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Technology and Innovation in Learning, Teaching and Education

First International Conference, TECH-EDU 2018
Thessaloniki, Greece, June 20–22, 2018
Revised Selected Papers

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Introduction

Digital technologies incorporate specific affordances and thus offer powerful tools that support teaching, learning, and education in general. Learning models and instructional strategies are transformed and find a context configured by technologies to be applied and contribute to learning benefits. In 2007 researchers from the field of digital technologies for an inclusive society in general and in special needs in particular started the first conference "Software Development and Technologies for Enhancing Accessibility and Fighting Info-exclusion, DSAI" in Vila Real, Portugal. Since then, eight DSAI conferences followed and an active research community was formed. The DSAI conference attracted researchers from the field of technologies in sports, health, and well-being who presented their research results at DSAI. In 2016, the first conference on "Technology and Innovation in Sports, Health, and Well-being, TISHW" appeared parallel to DSAI. In both conferences, papers on digital technologies for an inclusive society were presented and concerned education. One more time, the research community expanded and on June 2018, the first "International Conference on Technology and Innovation in Learning, Teaching and Education, TECH-EDU" organized at the Aristotle University of Thessaloniki, Greece.

The International Conference on Technology and Innovation in Learning, Teaching and Education, TECH-EDU is an international initiative that promotes all the aspects of learning technologies. The conference covers theoretical, technological, pedagogical, organizational, instructional topics, as well as policy issues regarding technologies and innovation in education.

TECH-EDU aims to serve as a forum for academics and researchers from around the world to present their current work. TECH-EDU gives emphasis to applied research relevant to educational practice. In a more generic scope, the conference aims to encompass broader issues determining technology and innovation integration in practice, including learning and teaching, instructional design, curriculum, learning environments, teacher education, and professional development, assessment and evaluation, etc.

TECH-EDU 2018 accepted peer-reviewed contributions for a main track and six special tracks, which were organized by leading researchers in their corresponding fields.

"New Technologies and Teaching Approaches to Promote the Strategies of Self and Co-Regulation Learning" was organized by Daniela Cristina Carneiro Pedrosa, José Paulo Cravino, Leonel Caseiro Morgado, and Giuliana Dettori. Athanassios Jimoyiannis and Gavin Baxter were the organizers of "eLearning 2.0: Trends, Challenges and Innovative Perspectives." J. Bernardino Lopes and Cecília Costa organized "Digital Tools in Science and Technology Learning," while Sofia Balula Dias, Sofia Hadjileontiadou, and Leontios Hadjileontiadis were responsible for the track "Exploratory Potentialities of Emerging Technologies in Education." "Building Critical Thinking in Higher Education: Meeting the Challenge" was organized by

Caroline Dominguez, Rita Payan, Catherine Dimitriadou, and Daniela Dumitru. Finally, Paulo Martins, Ana Margarida Maia, and Jorge Borges organized "Improving Quality in the Adoption of New Learning Technologies and Methodologies."

All the papers of the TECH-EDU 2018 conference were accepted via a double-blind review process.

The first TECH-EDU conference owes its success to all the contributors. We thank the authors for submitting quality papers as well as the members of the Scientific Committee who contributed to the topics of the conference and the review process. We also thank the Special Track organization chair and all the organizers, for managing and reviewing the submitted articles. We thank the publication chair for the preparation of conference proceedings, as well as all the members of the Organizing Committee for organizing and contributing a successful conference.

May 2019

José A. Diniz
Tassos A. Mikropoulos
Meni Tsitouridou

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Putting to Test a Model of Self-evaluation of the Learning Method in an e-Learning Environment

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Abstract. This paper describes the process and results of a study that put to test a model of self-evaluation of the learning processes which had emerged from a previous study. As in the previous study, this study examined self- and co-regulation strategies, in particular learners' assessment strategies that learners perceived to have used during a university course within an e-learning environment. In the previous study [13], collective evaluation of the targeted learning content—a co-regulation strategy—, and to a lesser extent, individual environmental control, both predicted individual self-evaluation of the study method. Using the same research method, the study presented in this paper aimed at examining learners' self-evaluation of their study method to test if a similar explicative model emerged. Furthermore, the present research studied two student groups, learning within the same course but with separate instructors. Studying two groups enabled to compare perceived regulation of learning strategies used. Subjects were postgraduate students in Educational Sciences studying on a digital campus in a French university during the academic year 2017–18. Data was collected using the ERICA scale [15]. The study found that the same explicative model applied, though the explicative power of the model was weaker. It also revealed that the two groups of learners did not differ significantly. These findings are discussed followed by suggestions for the design of e-learning environments.

Keywords: Self-regulation · Co-regulation · Learning strategies · Assessment · Self-evaluation

1 Context

Almost 30 years have passed since researches took to studying ways learners manage their learning under the banner of Self-Regulated Learning (SRL). Initially,

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interest was focused on strategies used by students in primary and secondary education. Zimmerman and Martinez-Pons [24] found that students who were better self-regulators and had used more regulation strategies were those who achieved better academic results. Researchers have since distinguished between motivational, cognitive and affective dimensions related to regulating learning. One strand of research in the field has referred more readily to metacognitive strategies learners use [16]. Recently, the study of strategies for learning has shifted to include regulation that involves other learners in a reciprocal manner. A shift of focus from the individual learner to the group has also attracted interest [3,7,11,12,20,21,23].

The research presented in this paper was conducted as part of a research program inquiring into the relationship between environmental conditions and strategies to regulate learning. The relationship between the environment and regulation of learning has not attracted much attention. The relationship between the environment and SRL strategies needs more attention for several reasons. The first reason pertains to the social-cognitive [1,2] backdrop of research in the field in which the environment is a constituent part. The human environment has received some attention, though tittle attention has been directed toward the material environment. Material environments are constantly evolving. This is particularly true of digital environments which are now ubiquitous in education. The interplay between the environment and the learning process should not be neglected as environments can be enabling to different degrees in terms of their ability to provide support for different types of learning strategies. Some strategies may be preferred by some individuals while others may be more effective for successful learning. The second reason to study the relationship between environments and learning processes is that knowledge needs to be generated about cognitive ergonomics and the affordance of contemporary environments [6]. A third reason for interest is the necessity to study strategies that learners use in educational environments that rely on peer interaction. A social-constructivist view of learning often guides instructional design of online learning environments in which peer interaction is foundational. Past research in the field of SRL and metacognition has by large been focused on the individual learner. Future research necessitates taking into account the paradigm shift and explore regulation of learning in digital learning environments designed around peer-interaction.

2 Theory

Research in the field of SRL has taken a turn. Reciprocal regulation between peers and groups of learners regulating their learning collectively, referred to as socially shared regulation, are now in the spotlight of several researchers [3,7,10–12,16,20–23]. Based on the theoretical model developed by Kaplan [9] (see Fig. 1), a self-report tool to measure the perceived frequency of use of self-regulation strategies, including two co-regulation strategies, was used in this research.

A word about what is referred to in this paper when using terms to describe regulation of learning will be useful. In this paper designations concur with Kaplan's [14] in which co-regulation is used as an encompassing term to designate regulation of learning that involves interaction with others. Two categories are included under the banner of Co-Regulation: Reciprocal Regulation and Collective Regulation. The former designates regulation from the standpoint of the individual in relationship with other persons, whereas the latter designates regulation taking place at the group level. Referring to collective regulation entails a change in the unit of observation—from the individual to the group as entity.

The individual and collective regulation of learning scale ERICA [15] enables to measure strategies at the macro-level [4]. Four macro-level regulation of learning strategies measured by ERICA are viewed as individual and two are viewed as collective. Strategies are summed up in Table 1.

Table 1. Phases and learning regulation strategies measured with ERICA [15]

Phase	Code	Regulation strategy
Anticipation	IAR	Individual anticipation of materials and references
	IEC	Individual environmental control
Monitoring	ITM	Individual tracking and monitoring
Assessment	CEC	Collective evaluation of content
	IEM	Individual evaluation of method
Decisions	CDM	Collective decisions for method change

Measures at the macro-level enable to detect patterns in regulation. Patterns of regulation should be understood as snapshots within contextualized situations of learning that depict the group being studied within that situation at a specific moment in time. This approach provides for comparisons to better understand the interplay between environmental conditions and Self-and Co-Regulated Learning (SCRL). The aim of the research presented here was to compare results from two groupes of students with results from a previous study. In both studies the students took the same course in the same online first-year postgraduate program in Educational Sciences. As mentioned, in the present study two groups participated. Each group used much of the same resources but each had a different instructor. The studies explored strategies that contributed to the assessments learners made of their study methods. Individual Evaluation of the learning Method (IEM) was selected as the criterion for the studies to analyze the relationship between IEM and the other SCRL strategies measured with ERICA. IEM fits into the theoretical cyclic process of regulation at the step just prior to decision making. On the basis of IEM, a decision can be made to keep using a method already in use or to change methods during subsequent efforts (see Fig. 1).

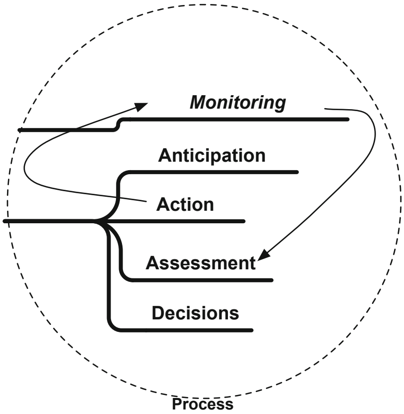

Fig. 1. Regulation of learning phases model [9]

The previous study ($N = 37$) explored links between learners' self-assessment strategies and other strategies to regulate learning, using multiple regression analyzes performed on data that was self-reported with ERICA by first-year postgraduate students during the 2016–17 academic year. The same terrain was used for the study presented here, with students taking the course during the 2017–18 academic year. In the 2016–17 study, the main strategy that contributed to IEM (71% of the proportion of variance explained by the model) was Collective Evaluation of Contents (CEC) targeted by the learning. CEC pertains to a collective strategy in which peers gauge and appraise the objects of knowledge at which they aim their learning. The model that emerged from that study had a second predictor variable. The second variable, which accounted for a smaller portion (29% of the proportion of variance explained by the model), was the control individuals exert on their learning environment, namely Individual Environmental Control (IEC). The model is represented in Fig. 2.

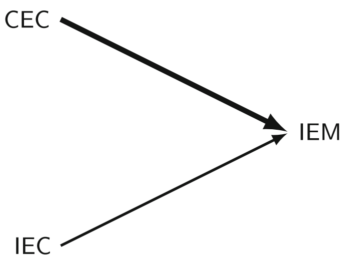

Fig. 2. Model of strategies of regulation that predict self-evaluation of the learning method resulting from a study with 2016–17 master's students (adjusted $R^2 = 0.47$) [13]

3 Method

In this study, data was self-reported using an online version of the ERICA questionnaire [15], made available on a server using Drupal™ software and an installed Webform module. The questionnaire, which contains 30 items, was administered during the last week of a four week compulsory course on quantitative data analysis during the second semester of the 2017–18 academic year. Participants were first-year students preparing for a Master's degree in Educational Sciences at a French university, enrolled in a distance education online program on the digital campus for education sciences.[1] The Learning Management System (LMS) used was BlackBoard Learn™. Students who had chosen to major in social work and healthcare education plus those majoring in adult education were assigned to group A. Students who had chosen to major in the formal education professions were assigned to group B. Each group had its own instructor.

The instructional design used with group A was based on the cooperative learning method Learning Together [8]. The instructional design deployed with group B used both individual and small group activities similarly to group A, but with more emphasis on individual activities. Participants were encouraged to respond to the questionnaire. The researchers' commitment to confidentiality and to the preservation of respondents' anonymity was communicated orally and on the questionnaire web-page.

Descriptive statistics pertaining to each group were computed. Next, a multivariate analysis of variance (MANOVA) was carried out to test the null hypothesis of differences between the two groups. Followed were multiple regression analyzes on the collected data to derive a self-evaluation of the learning method model or models. Models were then compared between those resulting from the present study and the model derived from the previous study [13].

4 Results

Analyzes were performed using R, version 3.4.3 [19]. Internal consistency analyzes of the measures carried out with ERICA were done using Chronbach's alpha to estimate reliability. Results were satisfactory for all dimensions: IAR ($\alpha = .77$), IEC ($\alpha = .84$), ITM ($\alpha = .81$), CEC ($\alpha = .78$), IEM ($\alpha = .73$), CDM ($\alpha = .86$).

Respondents ($N = 70$) were students from group A majoring in social work and health education plus those majoring in adult education ($n = 37$; 81% female, 19% male; age $M = 35.41, SD = 7.13$) and students from group B majoring in the formal education professions ($n = 33$; 85% female, 15% male; age $M = 32.15, SD = 5.35$). Table 2 provides descriptive statistics for each regulation strategy per group. A t-test on age means indicated a small but statistically significant difference between the two groups [$t(68) = 2.14, p = .036$].

[1] Formation et Ressources en Sciences de l'Éducation (FORSE) <http://www.sciencedu.org> is a digital campus run conjointly by two French universities and the French national centre for distance education.

Table 2. Descriptive statistics of measured regulation strategies

Strategy	Group A				Group B			
	Min	Max	M	SD	Min	Max	M	SD
IAR	1.8	4.0	2.85	0.59	1.2	4.0	2.91	0.71
IEC	1.0	4.0	2.92	0.79	1.2	4.0	2.96	0.71
ITM	0.0	4.0	1.50	1.10	0.0	4.0	1.73	1.05
CEC	1.0	3.4	2.28	0.65	0.6	3.0	1.95	0.76
IEM	1.2	3.2	2.26	0.52	1.0	3.0	2.10	0.60
CDM	0.0	3.0	1.34	0.80	0.0	2.8	1.01	0.82

Note: Values for measured regulation strategies span from 0 to 4.

The next step consisted of comparing the two groups for differences in perceived frequency of use of strategies. A MANOVA was carried out on the regulation strategies variables. Results did not reveal significant differences in perceived use of regulation of learning strategies between the two groups $[F(1, 55) = 1.22; ns]$. As no significant differences were found, following analyzes were done on all respondents' data (groups A and B) as a whole.

Analyzes that followed were intended to explore regulatory strategies (the independent variables) that are conducive to the self-evaluation of the learning method (the dependent variable). Multiple regression analyzes were performed for that purpose. A step-by-step (bidirectional) analysis, adequate for an exploratory phase [17], was performed using the Akaike Information Criteria (AIC). The resulting explanatory model indicated that the co-regulatory strategy Collective Evaluation of Content (CEC) as well as the individual regulatory strategy Individual Environmental Control (IEC), jointly contributed to the Individual Evaluation of Method (IEM) regulation strategy (see Table 3). IEM pertains to the self-evaluation of the method the learner used for her or his learning. The result of the assessment of the linear model assumptions [18] warrants the model with the two predictor variables CEC and IEC (see Table 4).

Table 3. Multiple regression analysis of regulatory strategies explanatory of self-evaluation of learning methods

	IEM					
	n	β	β error	R^2	Adj. R^2	F
IEC		0.18^{*}	0.09			
CEC		0.21^{*}	0.09			
	63			0.17	0.14	$(2, 60) = 6.03^{***}$

$^{*}p < .05$; $^{**}p < .01$; $^{***}p < .001$.

Table 4. Assessment of the assumed linear model assumptions

	Value	p	Decision
Global stat	1.29	0.86	Assumptions acceptable
Skewness	0.17	0.68	Assumptions acceptable
Kurtosis	0.91	0.34	Assumptions acceptable
Link function	0.21	0.65	Assumptions acceptable
Heteroscedasticity	0.00	0.99	Assumptions acceptable

These results were similar to the ones found in the previous study though the proportion of variance explained was 14%, a lower percentage to the one found in the previous study in which the proportion of variance explained was 47%.

A final step consisted of calculating the relative importance of each contributing strategy to IEM. Following recommendations by Gromping [5], decomposing the variance using the LMG method was used. Metrics were normalized to sum to 100%. The percentage of contribution to the variance by each predictor resulted in 55% for CEC and 45% for IEC, compared to 71% and 29% respectively in the previous study.

Illustrating the model (*cf.* Fig. 2) will be helpful before proceeding to discuss results. An example of a strategy that belongs to the macro-level collective strategy of evaluation of the targeted learning content (CEC) is when learners have discussions with one another to calibrate targeted outcome. These discussions, combined (though to a lesser extent) with strategies pertaining to control over the learning environment (IEC), such as setting oneself up in a place where one will not be distracted when learning, predict learners' use of strategies for the evaluation of their individual learning methods (IEM). An example of a strategy that belongs to the latter is to sometimes question one's learning method. In other words, more discussions held among learners on terms of reference, plus increased attention to suitable conditions to learn in, are indicative of the more frequent practice of checking out adequacy of the way one is developing one's knowledge and reflecting on the cognitive processes (metacognition) used to comprehend information and improve mastery of the topic being learned.

5 Discussion

Contrary to the previous study where the main strategy that contributed to self-evaluation of the learning method was CEC, in the present study both CEC and IEC have a similar relative importance in their share of the proportion of the variance explained by the model. Additionally, although the same model emerged from both studies, there is a considerable difference between the proportion of variance explained by the model in the present study (14%) and the previous one (47%). Regardless, it is the same model that turned up in both studies.

One of the instructors (group A) was the same as the one in the previous study. He had used the same instructional design both times. The research reported here had participants studying with another instructor too (group B). Nevertheless, no statistically significant differences were found between the frequency of perceived use of regulation strategies by the students in each group. Perhaps the use of the same LMS, interfaces, basic learning material and a similar learning design contributed more strongly to perceived regulation of learning and so no significant differences were found. Future studies within different environmental conditions should help clarify this.

In both the present study and the previous one, CEC which is a collective strategy entailing discussion among learners, was linked to the individual strategy IEM. The latter concerns assessment of the learning process, as opposed to the former which is an assessment related to the targeted outcome. The analysis of data from these studies underlines the contribution of the co-regulatory strategy CEC to judgments the learners made as to the adequacy of their past individual learning processes in order to make fitting methodological choices. The assessment phase is crucial to the regulation of learning. As mentioned, variations between the two groups in the present study were not statistically significant. However, a difference in the proportion of the variance explained by the model in the present study compared to the previous one is apparent. Differences may be due to small changes in the characteristics of the learning environment (pedagogical method, instructor and group composition, etc.). Nonetheless, the need for control over the learning environment and the need for channels to communicate among peers in order to reciprocally gauge content related goals in view of adjusting learning methods, have implications for the designs of e-learning environments. The results of this research suggest implementing features in the software used for education as well as designing the digital environment on top of it in two ways. The first is by making it possible for learners to adjust the environment to suit their individual preferences. The second is by providing communication channels for learners to interact through.

The environment can be thought of in terms of choices about where one wishes to study (at one's desk at home, a public library, outdoors...), the sound in the environment (silence, music, chattering, chirping birds...), the lighting of the environment, its warmth and other comfort related aspects. These environmental considerations are independent of the use of materials and means of communication to support the learning. The environment can also be conceived of in terms of media and tools that in digital learning environments can be altered to varying degrees. Interactions between the learner and the digital environment can shape the environment. Depending on the design infrastructure, some adjustments could be yielded to learners. Adjustments could be the ability to shape an interface such as placing components of the interface at different locations on the screen. Adjustments could also be the ability for the learner to add components with specific services such as announcements from social network posts or to remove services such as an unused online calendar. Regarding communication services, digital environments often integrate forum modules for asynchronous discussions as well as chat modules for synchronous discussions. A messaging module is often integrated too. Other communication channels could be made available. Even if they are not, gateways to other media and applications can be opened as well as instructions can be given as to the option of using audio or video for online discussions using other tools. Most importantly is the need to implement e-learning environments in a manner that enables learners to have discussions among themselves.

6 Conclusion

The study put to test a model for self-evaluation of the learning method that resulted from a previous study [13] in similar environmental conditions. The model that followed from this research corroborates the one that turned up previously. This suggests that in likewise environmental conditions, analogous patterns of regulation of learning are present with regard to the evaluation by learners of their learning methods. Learners also perceived their frequency of use of strategies to regulate their learning in a comparable manner even though separate instructors were assigned to the groups in the present study. Beyond this first indication, strategies that contributed to individually evaluating methods used for learning were those strategies pertaining to control by learners over their learning environments as well as strategies pertaining to co-evaluation of the targeted learning contents. Both these macro-level strategies contributed to individuals' evaluation of their learning methods. However, the proportion of variance explained by the model was considerably lower in the new study. It was lower to such an extent that the model has little usefulness. Other still unidentified variables play important roles in the assessment of the adequacy of the deployed learning methods by online students.

Future studies using other research methods in parallel such as through the use of trace data on e-learning LMSs, should enable to observe the degree of association between self-reports and actual use of available control that digital environments offer as well as actual use of communication services by learners. Attempting to understand links between self- and co-regulation perceived use and actual usage will also enable further testing of the empirical validity of the self-evaluation of the learning method model.

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Co-regulated Learning in Computer Programming: Students Co-reflection About Learning Strategies Adopted During an Assignment

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Abstract. Higher education students exhibit difficulties in learning computer programming, particularly transitioning from initial programming to advanced programming, so it's necessary to develop effective teaching strategies.

We developed the SimProgramming approach to help students overcome learning difficulties transitioning from entry-level to advanced computer programming, by developing appropriate learning strategies. The students perform a specific set of tasks in a learning environment that simulates business operations, developing a problem-based learning assignment. One of those tasks is filling biweekly individual self-reflection and co-reflection forms.

This approach was implemented at the University of Trás-os-Montes e Alto Douro (Portugal), in a 4th semester course of two bachelor programmes: Informatics Engineering and ICT. The students provided 37 biweekly forms, on which we conducted thematic analysis to identify their strategies for co-regulation of learning during the assignment.

Students are adopting different strategies in each phase of the approach. Early phases are devoted to organization, planning, and transformation of information, and later phases focus on applying theoretical knowledge and hands-on programming.

We recommend including this type of pedagogical task (biwekly self-reflection and co-reflection forms) in educational practices, in view of their contribution to improving self- and co-regulation learning strategies.

Keywords: Co-regulation learning · Computer programming · SimProgramming approach · Reflection

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1 Introduction

There is a growing need for skilled professionals in computer science [1]. However, Higher Education students exhibit difficulties learning computer programming, particularly transitioning from initial programming to advanced programming [2], with high rates of academic failure being common. Students' difficulty in learning to program is particularly noticeable in the transition from entry-level programming to advanced programming [2].

The reasons include the teaching approach and the attitudes/strategies used by students in computer programming [3], including the lack of motivation and involvement in study [2, 3]. Also, most students come to the job market lacking the necessary skills to meet the expectations of employers [4], such as teamwork and cooperation skills [5].

In advanced programming courses, the level of complexity is much greater than entry-level programming courses. Differences impacting students include large code sizes, the need to work in teams of varying size with associated communication issues, and a dynamic environment where regular changes to existing code become necessary. When applying techniques to address this complexity, such as architectural styles, e.g. Model–View–Controller (MVC) [6], students have difficulties grasping the rationale of the technique and other software engineering concepts [7]. There are also other complex programming skills [8] and social skills [5].

We seek to employ in this regard the concept of Self-Regulated Learning (SRL), a key element for success in higher education, which allows students to be proactive managing their learning and developing life skills [9]. The application of SRL strategies typically predicts high academic achievement [10] and can be improved with appropriate interventions [11]. Also, it is recommended that teachers promote and contribute towards students' development of metacognitive knowledge about academic work and task-specific strategies [12].

In computer science, students that apply SRL and metacognitive strategies have good performance [13]. However, most students are not aware of SRL and metacognitive strategies that can be used, so instilling them is important [14].

Co-Regulated Learning (CRL) also helps understand the process of regulating student learning [15]. In the context of computer programming, CRL helps students improve their programming skills [16], by providing a set of resources and skills for working with others [17].

We developed the SimProgramming approach [18–21] and applied it in the academic year 2013/2014 to the Programming Methods 4 (PM4) course, part of the third year of the bachelor programmes in Informatics Engineering (IE) and in Information & Communication Technologies (ICT) at the University of Trás-os-Montes e Alto Douro (UTAD), Portugal.

In the SimProgramming approach, the course syllabus requires students to develop a problem-based learning (PBL) assignment with a specific set of tasks based on the conceptual foundations of SimProgramming and is described further ahead in Sect. 3.

One of these tasks is filling out biweekly forms for self-reflection and co-reflection. These are handed out to each student's team and focus on their biweekly performance developing the course assignment. We conducted thematic analysis of 37 biweekly forms seeking to identify the SRL and CRL strategies mentioned by students during the development of the assignment.

In previous studies, we described the SRL and CRL strategies used by individual students, collected via weekly forms [19] and semi-structured interviews [20, 21]. In this paper, we look at the team perspectives on co-regulation learning strategies, collected via biweekly forms.

2 Background

The cyclical model of SRL is based on the social cognitive theory proposed by Zimmerman, which has three phases for self-regulation: (1) forethought, which is the goal setting and planning before the assignment/study; (2) performance, which is when the students use various strategies, monitoring and controlling their learning; and (3) self-reflection, reflecting about the learning process after assignment/study [22–24].

In fact, SRL is considered a meta-process [23] in which students are proactive and have control over their cognition, behavior, emotions and motivation through the use of personal strategies to achieve their established personal goals [25].

Self-regulated learners are active participants in their learning and develop academic skills [26]. They are generally successful and have good academic performance [10], adopting various learning strategies [23] during an academic assignment, such as cognitive, behavioral and motivational strategies to improve and guide the learning process [27].

However, university students may find it difficult to regulate their learning [28], which in turn may lead them to abandon courses [29], or not finish them on time [24].

SRL provides students with opportunities for getting acquainted with effective practices/strategies for their study, such as: time management; resource management; environmental management; incorporating feedback; and management of learning objectives and results [26, 30]. Students construct their own meanings, goals, and strategies from the information available in the external environment and in their own minds [31].

SRL strategies (SRLS) are specific skills that are part of the SRL process and can be taught to students for them to apply in real contexts [22, 23], such as: goal setting and planning, organizing and transforming, seeking information, rehearsing and memorizing, environmental structuring, seeking social assistance, self-consequences, records and monitoring, reviewing records, and self-evaluation [23].

SRLS help students obtain and retain knowledge about the adoption of a methodological approach and structure their learning, affecting their results [10]. According to Wang et al. [32], the application SRLS is usually a predictor of good academic performance.

CRL is understood as a social regulation of learning, in which students temporarily regulate their cognition, behavior, motivation, and emotions in situations of temporary coordination of regulation with other people (teachers or peers) [24, 27, 33]. This interaction of the student with others allows him/her to internalize regulatory processes (ibid.).

Team regulation, social activities and learning co-regulation are important for successful collaboration, because team members contribute to building shared dynamic mental models, and awareness towards a successful decision-making process [34]. In addition, cognition and feelings can be encouraged by peers or teachers to improve and increase understanding of tasks [35]. CRL helps understand the processes of student regulation [15], when students co-regulate learning, they have the potential to improve their learning self-regulation skills [36].

In computer programming, CRL helps students improve their programming skills [16], as it provides students with a set of outwardly resources and skills (seeking social help, evaluating others' ideas, monitoring tasks) [17].

Reflective learning helps students become more aware of the learning process and their difficulties [37]. When students make effective self-reflection, they analyze how they learned, how they understood the objectives of the learning process and what is necessary to create conditions for success [38]. It also encourages students' critical thinking about their abilities, and reflects on improvement strategies for the learning process, making them aware of the learning advantages in the future, and helps them develop transversal skills [37]. The interaction between compromise, self-control, autonomy and students' self-discipline allows them to regulate their own actions to achieve their learning goals [39].

On the other hand, reflective learning provides feedback to teachers, enabling them to readjust their experiences and pedagogical tools [38]. The use of a reflective diary is a technique that reinforces and stimulates reflection on the theoretical and practical component of work (ibid.).

The pedagogical context contributes towards learners' engagement and resolve to achieve learning outcomes [40]. In higher education, it is important to prepare students for the challenges of later professional practice and provide students with opportunities to develop their self-regulation and co-regulation skills, through activities that improve collaborative and active learning [32].

In engineering education in particular, learning approaches are typically not aligned with the requirements of the labor market [41, 42], not prioritizing skills aligned with professional realities, such as active learning or integrating knowledge [43].

Role-playing pedagogical techniques stimulate students to learn about similar real-world situations, with problem-solving, and active learning, providing opportunities to learn by doing and collecting feedback for building new knowledge [44]. They also help develop professional identities [45].

3 The SimProgramming Approach

The SimProgramming approach [18–21] is based on four conceptual foundations (ibid.): (1) business-like learning environment, (2) SRL; (3) CRL, and (4) formative assessment.

The SimProgramming approach was developed through iterative application and refinement, between 2011 and 2014.

Through these conceptual foundations, teaching strategies are adopted to stimulate SRLS and CRLS. The learning activity process develops along four phases, and students have specific tasks in each phase, with specific environment, roles, and deadlines during a course-long (i.e., semester-long) assignment [18–21].

Conceptual Foundation 1: Business-Like Learning Environment
SimProgramming stipulates the simulation of a business-like environment with the goal of promoting awareness of the professional reality and teamwork expectations, through role-playing, with each participant taking on a role. Also, Problem-Based Learning (PBL) is used to promote collaborative discovery for the resolution of the problem [46].

The course lecturer plays the role of CEO or general manager, taking responsibility for the course content and monitoring.

Other teaching staff of the course (e.g., course tutors or teaching assistants – henceforth “tutors”) play the role of project managers, providing close monitoring, mentoring, and feedback to students, based on the Scrum method for project management and agile software development [47].

Students play different roles as members of development teams and divide the work according to the role played by each member. One student acts as team leader and the remaining students handle subsets of work (“work packages”). The team leader facilitates the integration of information and guides the group [5], making sure that team members keep a global view of the project context and status, integrating knowledge. Other students have a specific role each, having to master their individual packages and cooperate with the team leader.

Conceptual Foundations 2: Self-regulated Learning (SRL)
The goal of conceptual foundation 2 is to promote students’ SRLS through active participation and engagement in meaningful activities before, during, and after completion of academic work [39].

The SimProgramming approach aims to promote students’ SRL strategies through active learning and engagement in meaningful activities before, during, and after completion of academic work [32]. Each student must solve his/her individual work packages and contribute to the overall perspective of the team problem. The team leader integrates research and exploration output of all members, reporting weekly at project management meetings. He/she also ensures the information flow within the team. Biweekly, each team completes a self-reflection form about his/her own work, pondering on what to do the following week, and reflecting upon the factors that prevented him/her from achieving the team and individual objectives. Students are encouraged to develop the concept of doing their work regularly and adopting study routines. This is done by creating a context where tasks are performed continuously, alongside feedback and monitoring support for self-reflection and self-regulation.

Conceptual Foundation 3: Co-regulated Learning (CRL)
The SimProgramming approach encourages *co-regulated learning* (*conceptual foundation 3*) with the aim of supporting the functional and effective development of a learning community of practices around problem solving. Students have two kinds of team tasks: reports and presentations.

In SimProgramming, students should be encouraged to get involved in pre-existing online communities of professionals (outside academia) not just to seek help, but to help other members of those communities, contributing to problem-solving and discussing the technologies under study or used in their future profession [2]. The search for help among professional communities is a common practice in real-world labour.

Tutors (in meetings, classes, and on-line) stimulate students' initiative when seeking social help (from peers, teachers, tutors, etc.), advising against using it as a mere least-effort approach to clarify doubts and difficulties. The tutors and the professor provide this support by advising on methods of gradual participation and involvement in communities, including suggestions of specific tasks for clarification of concepts, and advise on development of homogenous peer-based contributions and discussion, supporting community development, informal interactions, and debate, which can be promoted and monitored via a Facebook group for the course or other forms of groupware.

Conceptual Foundation 4: Formative Assessment

In real world labour it is well-known that companies conduct assessments of team performance. So, SimProgramming also employs Formative Assessment with the goal to improve self-reflection by providing management feedback (from tutors and from the Professor).

The Professor and tutors employ face-to-face and online contact to provide monitoring, meetings, and social media interactions, including motivational mentoring, coaching, and feedback on individual package status. The feedback is adopted as support for students' self-regulation and critical thinking. Assessment in SimProgramming takes two forms: formal self-assessment of individual students and hetero-assessment by team members at the end.

SimProgramming Phases: Learning Assignment Process

In the SimProgramming approach [18–21], the learning assignment is developed along four phases and students have specific tasks in each phase (Fig. 1), based on the SimProgramming conceptual foundations presented above. During all phases, weekly meetings take place between tutors and team leaders, providing feedback for motivation, self-regulation, possible support for technical doubts, and internal team issues.

What Are the Team Biweekly Forms?

The team biweekly form is where each team self- and co-reflects upon their work (teamwork and individual work), ponder on what to do the following weeks, and reflect upon the factors that prevented him/her or the team from achieving specific goals [18]. It acts as a reflexive diary with the goal of stimulating reflection about work performance.

Each team must answer 3 questions: (1) "What have you done these two weeks for the assignment?"; (2) "What will you do in the coming weeks for the assignment?"; and (3) "Any reason(s) for not completing the tasks?".

	Phase 1	***Phase 2***	***Phase 3***	***Phase 4***
Assignment Goals	Searching for information about the technologies under study;	Integration of technologies; .	Improving the assignment;	Final improvement of the assignment.
	Interacting in online communities;			
	Group work: Initiate problem-solving.	Group work hands-on examples	Final presentation with problem-solving	
Specifics Tasks	Report interaction in community of practice (team) Report interaction in community of practice (team)			Final Report (team)
	Weekly forms (individual) – all phases			
	Weekly meetings between team leaders and tutors - all phases			
	Report about learning progress (team) - all phases			Grids about self-assessment of individual students and hetero-assessment by team members (of individuals)
	Presentation of the team work – all phases			Extra task for extra credit or replacement credit (individuals or team)
Duration of the Phases	3 weeks	3 weeks	2 weeks	2 weeks

Fig. 1. SimProgramming phases: goals, specifics tasks and duration.

4 Teaching Context and Learning Assignment

4.1 Teaching Context

The course goal in PM4 is for students to develop the knowledge and skills necessary to develop web applications. Students start by working with the client-server concept of web applications and study their operation, including analysis of the HTTP protocol and the processing of its messages by web clients and servers. The syllabus for PM4 includes data formats and metadata for web applications, including the meta-languages SGML and XML, and languages specified by them. It then proceeds with the internal operation of Web clients and servers, including automation, and concludes with the study of various types of Web applications and the specific case of Web services.

In the previous year, students had experienced an early version of the SimProgramming approach in the PM3 (Programming Methods 3) course, which was focused on software architectures, and code complexity management techniques, such as concern independence, transparency, etc.

4.2 Learning Assignment in PM4

We combined proposals described in the literature about techniques of technology-enhanced learning [48] and face to face teaching techniques to support students during the assignment [19]. The tutors scheduled face-to-face meetings with team leaders, either individually or as a team, when they identified problems or difficulty fulfilling the tasks.

The Moodle LMS is used as the on-line environment for the professor and the tutors to track the development of the assignment and organize the tasks into modules over several weeks. Through the LMS, students are provided with supporting materials for development of tasks, scheduling, overall objectives of the assignment and specific objectives of each task, a forum for doubts and for contacting tutors, and other course materials (e.g. slideshows used in lectures). Also, other on-line tools are used to support students: e-mail, instant messaging (GTalk now called Google Hangouts), Facebook, and SIDE, which is a locally-developed course management system [49] for students to submit their completed tasks.

The learning assignment is based on PBL [46]. In PM4, a specific problem is assigned to each team, involving protocols, web applications, and markup languages. The goal of the problem is to lead students to develop skills on the development of web applications. Students must develop a technological solution using a web system and a given web access platform (e.g. mobile devices) and explain in detail (including code examples) how it is possible to exchange information between systems using different markup languages.

The SimProgramming approach was used throughout, along all the 4 phases, during 10 weeks of the academic semester, described ahead. In the 2013/2014 academic year, students formed 9 teams (Table 1). Most of the students participated in the previous course (PM3) and thus had prior contact with this approach.

All teams successfully achieved the learning goals. Of the 49 students, 44 attained a final grade.

Table 1. Nr. of the students in assignment

Teams	Nr. students with a final grade	Comments
P	6/6	- Were regular in delivery of individual tasks and teamwork - In the final weeks, the team presented some interpersonal problems among team members
Q	5/6	- Were regular in delivery of individual tasks and teamwork - Same team as in PM3, 2012/2013 (team H, Pedrosa et al., 2016) - One student quitted the assignment
R	7/7	- Same team as in PM3, 2012/2013 (team B, Pedrosa et al., 2016) - Were regular in delivery of individual tasks and teamwork. However, they did not submit two of the biweekly team forms

(*continued*)

Table 1. (*continued*)

Teams	Nr. students with a final grade	Comments
S	4/4	- Were regular in delivery of individual tasks and teamwork. However, they did not submit two of the biweekly team forms - Intervention of the tutor through meetings providing feedback and motivation
T	6/6	- Were regular in delivery of individual tasks and teamwork
U	6/6	- Were regular in delivery of individual tasks and teamwork
V	4/4	- Were regular in delivery of individual tasks and teamwork. However, they did not submit one of the biweekly team forms
X	3/5	- Were regular in delivery of individual tasks and teamwork. However, they did not submit four of the biweekly team forms - Intervention of the tutor through meetings providing feedback and motivation - Two students quitted the assignment, one them being the initial team leader
Y	3/5	- Were regular in delivery of individual tasks and teamwork - In the first weeks, the team presented some interpersonal problems among the members of the team - Two students quitted the assignment, one them being the initial team leader - Intervention of the tutor through meetings providing feedback and motivation - Initially the team was not achieving the objectives of the activity, however after the change of the team leader, the team showed good results
Total	44/49 (89, 8%)	- 44 of 49 students (90%) who registered for the activity obtained a final classification

5 Methodology and Data Collection

During the 10 weeks in which the assignment took place, each team had to submit its biweekly form as a team, i.e. 5 forms in total. The fulfilment of this varied slightly throughout the phases of the SimProgramming approach (Table 2).

Table 2. Delivery of biweekly team forms by teams, per SimProgramming phases

SimProgramming phases	Weeks	Nr. biweekly forms delivered	Total
Phase 1	Week 1	9	9
Phase 2	Week 3	8	15
	Week 5	7	
Phase 3	Week 7	6	6
Phase 4	Week 9	7	7
		Total	37

All the 9 teams initially enrolled in the assignment completed all phases of the SimProgramming approach, performing the requested tasks.

In the first week, all teams delivered the biweekly forms. In Phase 2, Phase 3 and Phase 4, occasionally, some teams did not submit the biweekly team forms (Table 2).

The 37 biweekly team forms were subjected to thematic analysis [50] aiming to identify the strategies of self and co-regulation of the learning (SCRLS) that students mentioned during the assignment.

Content analysis matrices based on the afore mentioned research literature were constructed on the types of self and co-regulation learning strategies (SCRLS), identification of difficulties in the assignment and on the factors that the students believed that influenced their motivation (Table 3).

Table 3. The three sub-categories about SCRL strategies identified in biweekly forms

Sub-categories	Definition
1. Organizing, planning and transforming strategies	Statements about the strategies that students adopted in the planning, organization, and processing of information for carrying out the assignment
2. Identifying the difficulties in the assignment	Statements about the difficulties students felt in doing the assignment
3. Co-reflexion strategies	Statements about the work performance

We organized content into categories, subcategories, indicators, and recording units (snippet sentences), which were restated during the process of content analysis. Then, we conducted a cyclical process of improvement, synthesis, and reflection.

The steps adopted for the data analyses were as follows:

1. Construction of content analysis matrices for each team, with the SCRLS (phrases/snippet sentences that students reported on the biweekly forms, explaining what they did). The content analysis matrices are composed of grid lines (each line for a strategy –the "indicators"); and columns to record in which week it was reported by team students. In the cells we entered codes identifying the team reporting that strategy that week (e.g. E.3).
2. Afterwards, we developed general syntheses of each team for each of the indicators.
3. For each subcategory of the strategies (e.g. Organizing and planning strategies) we counted the number of teams who reported each indicator (e.g. 1.1 = 113).
4. Finally, we did a general synthesis of the indicators in each of the phases.

In a first moment, one researcher (one of the authors of this paper) created the content analysis matrixes (with the categories, the subcategories, indicators and the recording units). After this, another researcher independently validated or suggested changes to these content analysis matrixes. When changes were proposed, they were discussed later until both researchers reached an agreement. Finally, the final version of the content analysis matrixes was validated by all the researchers.

6 Results and Discussion

In the biweekly team forms, we found that the teams mentioned “Organizing (O), Planning (P) and Transforming (T) strategies” to carry out the assignment (Table 4).

In the first phases (Phase 1 and Phase 2), the most mentioned strategies by teams are team meetings to define tasks (n = 24), information research (n = 15), application of knowledge related to practice (n = 14), elaboration of notes on the information found (n = 14) and also the division of tasks among the team members (n = 13). Other strategies were also mentioned by the teams.

In the Phase 3 and Phase 4, the strategies that were most mentioned by the teams are related to the transformation of the information found through notes (n = 8), and the application of the information in practical context (n = 11). Likewise, the teams had the concern to understand the research material (n = 8).

Table 4. Organizing (O), Planning (P) and Transforming (T) strategies

Indicators	SimProgramming phases			
	Phase 1 (n = 9)	Phase 2 (n = 15)	Phase 3 (n = 6)	Phase 4 (n = 7)
Information search (O)	8	7	1	0
Collected information (O)	5	9	2	3
Work plan development (P)	1	2	1	1
Understand the project goal	1	3	0	0
Recording practices online communities (O)	1	0	0	0
Meeting schedule with team colleague (O)	4	6	2	3
Meeting with tutor (O)	1	0	0	0
Division of tasks between team members (O)	5	8	2	1
Drafting notes about collected information (T)	6	8	3	5
Application of existing knowledge about the practice (T)	5	9	5	6
Understanding (learning) through the collected information search (T)	4	4	2	6
Team meeting to define task (P)	4	4	0	0
Defining specific tasks for next week (P)	9	15	5	1

Likewise, the teams identified and expressed in the biweekly forms the difficulties they experienced carrying out the assignment, as can be seen in Table 5. The most mentioned difficulty in all phases (Phase 1, Phase 2, Phase 3, and Phase 4) was the overload of work.

In the early stages (Phase 1 and Phase 2) the teams also reported difficulty meeting (n = 11). Subsequently, in the intermediate phases (end of Phase 2, and Phase 3) the teams also expressed difficulties implementing the practical component.

Table 5. Identifying difficulties in the assignment

Indicators	SimProgramming phase			
	Phase 1 (n = 9)	Phase 2 (n = 15)	Phase 3 (n = 6)	Phase 4 (n = 7)
Team meeting	3	8	1	0
Time management (TM)	2	0	0	1
Theoretical knowledge about the technology being studied	1	0	0	0
Team member quitting and/or inter-team relationships	0	1	0	1
The practical component implementation	0	3	1	1
TM due to work in other courses or tests	1	11	2	6

Regarding the co-reflection of team members on their tasks, (Table 6), the teams mentioned whether or not they had achieved their goals, and difficulties the experi-enced achieving the objectives of the task. In the intermediate stages (Phase 2 and Phase 3), the teams mentioned more emphatically that they were able to reach the goals but had difficulties. Throughout all phases, most teams reflected specifically on the tasks performed.

Table 6. Co-reflection

Indicators	SimProgramming phases			
	Phase 1 (n = 9)	Phase 2 (n = 15)	Phase 3 (n = 6)	Phase 4 (n = 7)
Co-reflection (CR) - Achieved the biweek goals	3	3	2	6
CR - Achieved the goals with difficulties	3	10	4	0
CR - Failed to meet goals due to difficulty holding a team meeting	1	1	0	0
CR - Failed to meet objectives due to overload of work with other courses	0	1	0	0
CR - Reflection on specific task	3	6	4	6

Throughout the phases of the SimProgramming approach, the teams mentioned, in the biweekly forms, the adoption of several different strategies in each of the phases.

In the first phases (Phase 1 and Phase 2), the organization and planning strategies were the most mentioned ones. In all phases, the strategies that stand out are related to the application and transformation of information, writing notes on the collected research material, the application of the practical component (programming), and the respective understanding (learning) of the research material. These strategies are skills necessary for the development of teamwork and in the context of the world of work. Students have improved their skills during the SimProgramming approach phases and are better prepared for transitioning to the professional practice world.

The teams identified difficulties in time management, namely, difficulties due to the excess of tasks and tests in the various courses throughout the semester. In the initial phase, the teams mentioned difficulties holding team meetings. Subsequently, the difficulties are related to the implementation of the practical component.

Likewise, team members were involved in a process of reflection on their learning, explaining whether the team had achieved the goals of the SimProgramming approach or not. They also identified occasional difficulties in achieving the objectives, especially in Phase 2 and Phase 3. Throughout all phases, it was verified that as a team, the students reflected in more detail on their performance.

7 Conclusions

Throughout the discussion, we argued that using biweekly team forms in PM4 (2013/2014) allowed us to verify that the adoption of this type of pedagogical task contributes to the improvement of strategies of self and co-regulation of learning, since it allowed students to be aware and reflect on essential competences to reach the learning goals, an important skill for the world of professional practice, confirming what was reported in an earlier work [19].

The students mentioned several types of learning strategies that they adopted during the assignment, namely: organization and planning strategies, identification of difficulties, and co-reflection on the assignment.

Problem solving strategies were not identified in the biweekly team forms, and neither were factors affecting motivation. In these forms, the teams focused on the detailed explanation of the work in terms of content, reinforcing the perspective of our previous experience in PM3 (2012/2013) [19]: it contributed to the development of competencies [19].

However, it was observed that in comparison to the individual weekly forms of the previous course, PM3 (2012/2013) [19], in the biweekly team forms of PM4 (2013/2014) the students (as a team) mentioned in more detail the strategies of information transformation. That is, in a team context, the students explained in greater detail the process of treatment of the collected material, and how they applied the knowledge obtained in the activity, in which the team's concern in understanding (learning) that material.

The difficulties found in the assignment are identical. Namely, the overload of work and the implementation of the practical component. However, in the team reflections, it is also mentioned the difficulty of getting the team to meet.

The students as teams can reflect on whether they have met (or not) the goals and identified their difficulties. Likewise, as a team they make a more detailed reflection on the tasks, especially when accompanied by the manager. This confirms earlier studies that found that tutors play an important role in students' self-assessment [30].

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eLearning 2.0: Trends, Challenges and Innovative Perspectives

Exploring the Role of Facebook as Collaboration Platform in a K-12 MOOC

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Abstract. This paper investigates the role of a Facebook group as a complementary communication and collaboration platform to the Udemy Q&A forum, in a computer programming MOOC developed for Greek vocational high-school students and hosted on the Udemy platform for two succeeding school periods. Students' contribution to the course content, as well as their interaction and collaboration with their fellow students and the instructor were observed, recorded and comparatively analyzed for both collaboration platforms. The results revealed that Facebook has the potential to play an important role in supporting the collaborative learning communities for the next generation of MOOCs.

Keywords: MOOCs · K-12 · Collaboration · Social networks

1 Introduction

Research on MOOCs focuses mainly on their application to adults, students or graduates of tertiary education, while there has been very little research on the benefits of their utilization for teaching subjects of lower educational levels and to students of younger ages [1].

Since 2013, when the first reference of MOOCs' utilization from K-12 students appeared in the literature, the few pilot surveys that have been carried out for K-12 MOOCs, highlighted several particularly important research issues requiring further research and investigation [2]. For example, MOOCs' low completion rates are unacceptable for K-12 education [3], successful students in K-12 MOOCs tend to be those who were already highly motivated [1], teacher's active engagement and participation in the MOOC is a core element for student achievement, [4] and students' interaction in K-12 MOOCs is quite low [1], which in turn has negative impact on their performance, as peer-interaction usually improves students' chances of success [5].

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Aiming to provide new research data about the potential role and value of MOOCs in pre-tertiary education, "PROG15: a computer programming MOOC" for supporting secondary education students in their exams for entering Greek universities, was designed, developed, implemented, observed and evaluated during 2015, within the context of a participatory action research design. The critical reflection on PROG15 findings resulted in a second, refined implementation of the MOOC during 2016, provided as PROG16.

Within the context of PROG15 and PROG16, students' motives for enrolment and participation, perceptions, attitudes and learning expectations from MOOCs and their potential role and value in secondary education, as well as students' overall experience were observed, studied and evaluated. The research outcomes revealed a quite positive picture regarding MOOCs' utilization in secondary education [6–8].

The educational resources of PROG15 and PROG16 MOOCs were hosted on the Udemy platform (www.udemy.com/domprogepal) in the form of video-lectures, e-books, links to additional external learning materials, on-line quizzes, tests and assignments. Additionally, the Q&A forum which is embedded in the Udemy platform was utilized for supporting communication and interaction among students and the instructor, contribution to course materials, and in general for developing and cultivating the collaborative learning community of PROG15 and PROG16 MOOCs.

Literature in the research of MOOCs found that social media is important to enhance the sense of community in MOOCs [8–10] and instructors use social media as a second channel to communicate with MOOC students [9, 11, 12]. Also, an appropriate selection of social tools could be helpful to engage students and improve their retention during the course [9, 11]. In this respect, aiming to strengthen collaboration, interaction and contribution within PROG15 and PROG16 learning communities, an open Facebook Group was created and used as a second communication and collaboration channel among students and the researcher [13–15].

The present work attempted to investigate and evaluate the role of this open Facebook Group as a second collaboration platform in comparison to the Udemy Q&A forum. More specifically, the present work investigated in a comparative way, during the two successive implementations of PROG15 and PROG16 MOOCs (1) students' contribution to MOOCs' learning content using FB Group and Udemy Q&A (2) students' collaboration and interaction with their fellow-students within the context of FB Group and Udemy Q&A (3) the effects of a number of pre-scheduled FB Group on-line meetings on students' interaction, collaboration and contribution to MOOCs' content, as well as (4) the instructor's role in the dynamics of PROG15 and PROG16 collaborative learning communities.

2 Methodology

We applied a mixed (quantitative and qualitative) methodology to research and evaluate the role of Facebook as a communication and collaboration platform in a K-12 MOOC, independently and in comparison to the embedded Udemy Q&A forum. More specifically, we quantitative tools were utilized to identify (1) students' contribution to the course content by counting their posts and comments (number and wordcount) on

FB Group and Udemy Q&A forum, and (2) students' interaction and collaboration with their fellow-students by counting their reactions (number) and comments (number and wordcount) on posts within FB Group and Udemy Q&A forum. Additionally, we conducted a qualitative content analysis on some of the most interacted posts and comments on both FB Group and Udemy forum, aiming to identify the dynamics of collaboration in both platforms.

2.1 The Study Settings

PROG15 and PROG16 MOOCs. Similarly to the typical MOOCs for higher education, PROG15 and PROG16 consisted of two modules (Fig. 3):

1. the educational resources, which were mainly provided in the form of video-lectures (each of the two MOOCs provided almost 5 h of video-lectures) accompanied by e-books, sets of slides, on-line quizzes, exercises, assignments and links to external resources for further study.
2. two spaces of communication, interaction and collaboration for supporting the learning communities:
   a. the embedded Q&A forum in the Udemy platform
   b. an open Facebook Group created for the purposes of PROG15 and PROG16 MOOCs

The main learning objective of both MOOCs was to support students' preparation for national exams on Computer Programming for entering Greek higher educational institutes. Computer Programming is a typical course taught in the 3rd grade (12th of the K-12 scale) of Greek vocational school classrooms and is one of the four courses, together with computer networks, modern Greek and mathematics, in which students of Greek secondary vocational schools, compete in national exams, for entering Greek higher educational institutes.

PROG15 educational materials and learning activities were organized in a syllabus which consisted of 32 lectures grouped in 9 sections, while PROG16 learning materials in a syllabus which consisted of 37 lectures, organized in 9 sections, too. The core components of both syllabi presented step-by-step the process of solving (understand, design, implement and test the solution) representative exercises of past national exams' tests on computer programming.

The basic target audience of PROG15 and PROG16 was secondary education students studying on the computer science sector of Greek vocational high-schools, preparing for national exams.

The Udemy Q&A Forum for PROG15 and PROG16. For every course the Udemy platform provides a forum for supporting communication and collaboration among the participants and the instructor. PROG15 and PROG16 MOOCs used the same Udemy forum, during 2015 and 2016 (https://www.udemy.com/domprogepal/learn/v4/questions). Within the forums' environment students could easily search for a question or post a new one, quickly view answers on any question that the instructor or other participants have posted, follow a question, read and respond to questions or comments their fellow students have made (Fig. 1).

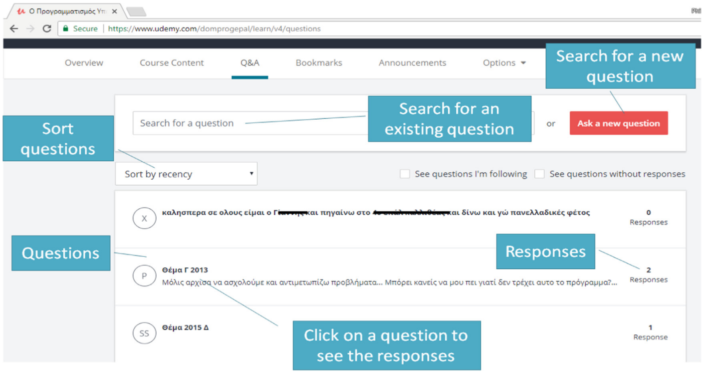


Fig. 1. The Udemy Q&A Forum for PROG15 and PROG16

The Facebook Group of PROG15 & PROG16 MOOCs. An open, publicly available Facebook group (https://www.facebook.com/groups/domprogepal) was created and used, together with the on-side Q&A Udemy Forum, as the second communication and collaboration platform for the participants and the instructor.

It was a typical Facebook group, publicly available for anyone to join, that allowed participants to come together around their common goal, which was to get prepared for national exams on computer programming.

Through this Facebook communication and collaboration platform, PROG15 & PROG16 students were able to share their ideas, express their opinions, discuss issues, post files, ask for help and support, upload their answers and solutions, peer-review and evaluate answers of other students, share content and in general interact and collaborate with their co-MOOCers and the instructor (Fig. 2).

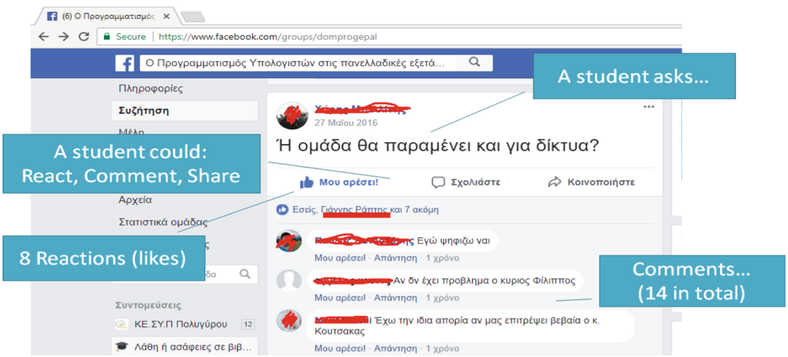


Fig. 2. The Facebook Group for PROG15 and PROG16

Like in any other FB group, the participants could:

1. Upload primary posts on the group, including text, images, links, videos or files.
2. Comment on group's primary posts
3. React (like) on group's primary posts or comments
4. Share a primary post uploaded by another student

2.2 The Research Process

PROG15 started 6 weeks before the 2015 national exams on computer programming and was offered as an organized MOOCs with the support of the researcher for 7 weeks (27/04 - 14/06/2015). PROG16 started 8.5 weeks before the 2016 national exams on programming and was offered for 9.5 weeks (01/04 - 05/06/2016).

The learning materials for both MOOCs were provided to students in a segmental manner. For PROG15 for example, only the first 13 lectures were available for students during the first week. The next 8 lectures were "unlocked" on the 1st day of 2nd week and the rest lectures on the 3rd. A similar segmental release pattern was followed from PROG16 too. This partial release of learning materials aimed to enhance students' participation in the two collaboration MOOC platforms as students had to work at a similar pace (at the same time using the same learning resources to solve the same issues) and would therefore had to face similar difficulties in which they could be supported by their fellow-students.

Every week, according to MOOCs' syllabi, students had to watch and study a specific set of provided video-lectures and learning materials and to solve assignments related to these materials. At the end of every video-lecture, the instructor informed students that they could use the FB group and/or Udemy Q&A forum in order to ask for help and support, in case they needed. Additionally, in all video-lectures students were also encouraged by the instructor to upload their answers and solutions on Udemy Q&A forum and/or on the FB group, support other students by answering their questions, peer-review, analyze and discuss the solutions and questions of their fellow-students. The instructor specifically stated that students could freely select the collaboration platform they preferred, or they could use both for communication and collaboration with their fellow-students. The estimated engagement time required from students to meet PROG15 requirements was 5–7 h per week for the provision (PROG15) period of 7 weeks.

Students, by posting and commenting on the Udemy Q&A forum and FB Group contributed to the courses' learning materials, while by commenting, reacting (e.g. FB likes) and sharing other students posts or comments, they interacted and collaborated with their fellow-students.

For observing and analyzing students' interaction and contribution data in the FB group, two on-line social media data collection tools were used:

1. the Grytics analytics and management tool for facebook groups (https://grytics.com/) which recorded the number of PROG15 and PROG16 posts, comments and reactions during the observation period. Using the above raw data Grytics calculated the "average group activity score" and the "average post engagement score"

2. the Sociograph.io analytics tool for facebook groups and pages (https://sociograph.io/) which recorded, analyzed and represented the distribution of PROG15 and PROG16 participants primary posts, comments and reactions during the observation period.

Udemy Q&A forum doesn't provide a tool for mass collection and analysis of data regarding students' collaboration and contribution to course content. In this respect, these data were collected and analyzed manually by the researcher.

During the running period of PROG15 and PROG16 the researcher was connected on a daily basis but on random hours into the FB group and Udemy Q&A forum, observed and supported the learning process, answered students' questions and encouraged their active participation and contribution to the course. The time the researcher spent on these processes was 10 to 15 h per week.

During PROG16, with the aim to strengthen the collaborative learning community of PROG16 nine live, on-line meetings in the FB Group of PROG16, were included in its syllabus and announced to the students, as an opportunity to discuss and exchange ideas with the instructor and the other participants, to ask questions, to solve queries and to help and support other students. The meetings were pre-scheduled (every Thursday night, from 21:30–22:30) and the instructor actively participated in all of them, as it was announced. Students' reactions on these pre-scheduled meetings, as well as, the instructor's role in the dynamics of the learning community were researched and evaluated.

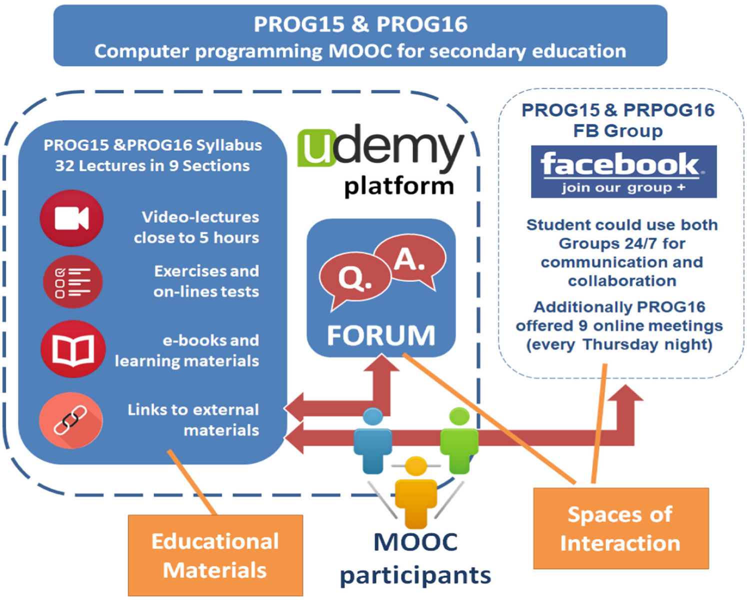


Fig. 3. The PROG15 & PROG16 MOOCs

During their running/provision periods PROG15 and PROG16 attracted 291 from a total of 2,382 and 265 from a total of 2.088 students, from various Greek Vocational Schools. Despite the small number of enrolled students, both courses can be considered as massive taking into account that they attracted more than 10% of the potential interested participants nationwide, which in any case is the largest audience ever attending such a course, at least in Greece. Out of the 291 registered students in PROG15, 151 were active (connected more than once, watched at least one video-lecture or solved an assignment, etc.), while out of the 265 registered students of PROG16 140 were active.

3 The Results

Students' contribution and collaboration data in PROG15 FB group and Q&A Forum were observed for 86 days (12 weeks). The observation period started on the first day of PROG15 (27/04/2015) and ended four weeks after the announcement of 2015 national exams results on computer programming (21/07/2015).

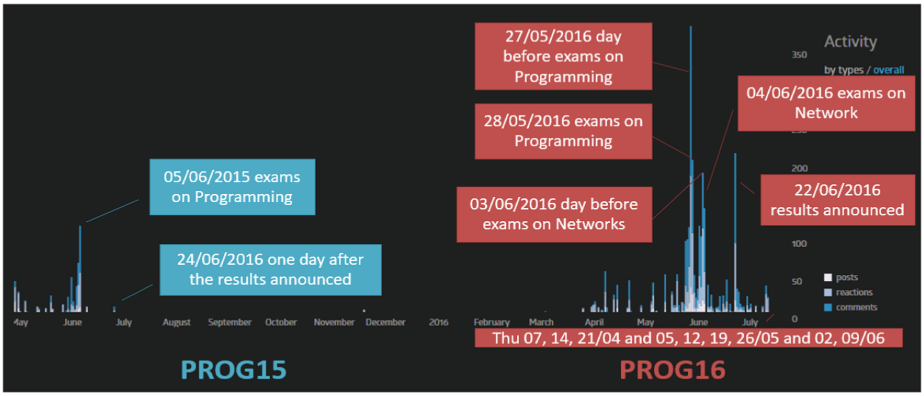


Fig. 4. PROG15 and PROG16 FB Group Posts, Comments and Reactions from 27/04/2015 until 20/07/2016

The contribution and collaboration data for PROG16 were observed for 111 days (14.5 weeks), starting on the 1st day of PROG16 (01/04) and ending 4 weeks after the announcement of 2016 national exams results on programming (20/07).

For each MOOC, we measured the number of students who joined and were actively engaged in the Udemy Q&A forum and the FB groups. The number of actively engaged students was increased from PROG15 to PROG16 for the FB Group, while the opposite occurred for the Udemy Q&A Forum. More specifically, 34 students were actively engaged in PROG15 FB Group, by posting, commenting, reacting or sharing at least once, while PROG16 engaged four times more students (114). In the PROG15 Udemy Q&A forum, 23 students were engaged, and this number was reduced to 10 (students) during PROG16 observation period. Table 1 clearly demonstrates that both

PROG15 and PROG16 students seemed to prefer (especially the PROG16 students) the FB Group for communication and collaboration with their fellow students, both in absolute numbers and in percentage.

Table 1. PROG15 and PROG16 Udemy & FB Total and Engaged users

		PROG15 (%)	PROG16(%)
Total users	Udemy Q&A	151	140
	FB group	41	146
Engaged users	Udemy Q&A	23 (15.2%)	10 (7.14%)
	FB group	34 (82.9%)	114 (70%)

3.1 Students' Activities Distribution in FB Groups over Time

Every bar in Fig. 4 represents the total number of primary posts, reactions and comments for a single day, as these were recorded by SocioGraph.io platform. More specifically, SocioGraph.io recorded students' activity in the PROG15 FB Group during the 25.6% (or 22 days) of the 86 days of the observation period.

The distribution of these activities demonstrated "peaks" at the beginning and end of the observation period and a "valley" during the mid-days. The most active days were (1) the exams days on programming (05/06), networks (03/06) and modern Greek (19/05) and few days close to them (before and after), (2) two days after PROG15's opening (28 and 30/04), (3) the days when new lectures were released (4 and 11/05) and (4) the day after the announcement of the results of national exams (24/06). As one could expect, the most active PROG15 FB group day is by far the programming exams' day (05/06/2015) with students connecting to the FB Group in order to communicate with their fellow students about the exams' tests, correct answers, their performance, etc.

During the PROG16 observation period the SocioGraph.io platform recorded students' activity in the FB Group on the 56.7% (or 63 days) of the 111 days, that is more than double increase compared to the "active days" recorded during the PROG15 observation period. During this period, the number of actively involved participants in the PROG16 FB Group increased 3.3 times, climbing to 114 participants, including the researcher. The distribution of activities demonstrated 10 small peaks, scattered during the 14 observation weeks before and after exams on programming, and on three groups of quite high peaks. The 10 small peaks were observed every Thursday (07, 14, 21/04 and 05, 12, 19, 26/05 and 02/06) during which the pre-scheduled one-line meetings took place on the PROG16 FB group, from 21:30–22:30. So, it seems that these nine pre-scheduled online meetings attracted students to connect on the FB group and to upload a number of posts, comments and reactions within the context of the FB group. The most active PROG16 FB group days were (1) the days before the exams on programming (27/05) and on networks (03/06), the exam days on those two courses (28/05 and 04/06) few days close to them (before and after), (3) the announcement day of programming results and a few days after (22/06). The most active day by far is the day before exams on computer programming with most students connecting to the platform until late hours in order to chat and joke with their fellow students about exams, while may others wanted to ask a last-minute question.

3.2 Posts, Comments and Reactions on PROG15 and PROG16 FB Groups and Udemy Q&A Forums

Active students' posts and comments in the Udemy Q&A forum were manually observed, recorded and analyzed by the researcher. On the contrary, students' posts, comments and reactions in the FB Group were observer by the Grytics Analytics platform. Active were the students that uploaded a post, commented or reacted on a post or comment at least once [13]. For every active FB Group participant, Grytics recorded the number of (a) posts, (b) comments (c) reactions (FB likes) and (d) shares. Similarly, for every active Udemy Q&A forum participant the researcher recorded manually the number of (a) posts and (b) comments.

The 114 active participants in PROG16 FB Group uploaded 209 primary posts on the group, that is almost 4 times more posts compared to the 53 posts uploaded in the PROG15 FB group. On average every active PROG16 student contributed to the course 1.83 posts on the FB Group, while every PROG15 active students 1.56 posts. The average PROG15 post contained 33.94 words and was almost 5 words longer than the average PROG16 post, which contained 27.76 words. PROG16 students contributed with their posts 5,802 words to the course content, while PROG15 students 1,799 words to PROG15 content.

Apart from their posts, students also contributed to course content with their comments. More specifically, PROG16 students contributed to course content 24,365 words, contained in the 1,875 comments (12.99 words per comment) either on primary posts or on other comments existing on the FB Group, while PROG15 students contributed to their course 2,802 words, contained in 211 comments (13.27 words per comment). This means that PROG16 students contributed to their course almost 9 times more words (in absolute numbers) than PROG15 students did.

FB Group and Udemy Q&A comments are also a mean of interaction and collaboration as student interacted with their fellow-students either by commenting their uploaded primary posts or comments already made on the collaboration platform. To this extend, the percentage of commented posts on a FB group gives a measure about a groups' degree of interaction and collaboration. In this respect PROG16 FB group was more interactive than PROG15 as less than half uploaded PROG15 posts were commented (the 25 of 53 or 47.2%), while more than 3/4 of the uploaded PROG16 FB posts were commented (the 159 from the 209 or 76%).

Another mean of interaction and collaboration among the PROG15 and PROG16 participants was the FB group reactions (FB likes) on posts or comments. Table 2 demonstrates that PROG16 students reacted almost 5 times more (they made 766 reactions) on their fellow-students' posts and comments, in comparison to PROG15 students, who reacted only 189 times.

Table 2. Summary of Facebook post related activities

Facebook groups	PROG15	PROG15	Evolution
General			
Number of primary posts	53	209	294%
Number of words (in posts)	1,799	5,802	222.5%
Words per post	33.94	27.76	−18.2%
Posts per student	1.56	1.82	17.3%
Number of comments	211	1875	789%
Number of words (in comments)	2,802	24,365	769.6%
Words per comment	13.27	12.99	−21.1%
Comments per student	6.21	16.45	164.9%
Comments per post	3.98	8.97	125.4%
Number of reactions	189	766	305%
Reactions per student	5.66	6.72	18.7%
Reactions per post	3.56	3.66	2.8%
Average group activity score	5.3	26.92	408%
Average group engagement score	11.53	21.62	88%
Primary posts			
Primary posts reacted	46	177	285%
Primary posts commented	25	159	536%
% of primary commented posts	47.16%	76%	61.7%
Primary Posts reacted or commented or shared	49	204	316%
Members			
Active members in the group	34	114	235%
Reacters	32	99	209%
Commenters	20	64	220%
Publishers	21	46	119%

In this respect we can support that PROG16 students, within the context of PROG16 FB Group, contributed more content to the course and at the same time they interacted and collaborated more actively with their fellow students, in comparison to PROG15 FB group participants.

The Grytics engagement score supports the above conclusion. More specifically, Grytics platform calculates the “Average Post Engagement Score” by summing up reactions + shares + twice the number of comments and dividing this score by the total number of primary posts. Table 2 show that PROG16 students were engaged with the uploaded content on the FB Group and consequently with their fellow-students almost two times more (21.62) than PROG15 students (11.53).

Additionally, by summing up all activities observed in a FB Group during an observation period (posts + comments + reactions + shares) and dividing this sum by the number of observation days, we get the “Average Group Activity Score”, which demonstrates on average how active a FB Group of students was. Table 2 shows that PROG16 FB Group students were almost 5 times more active (26.92) than the PROG15 FB Group students (5.3).

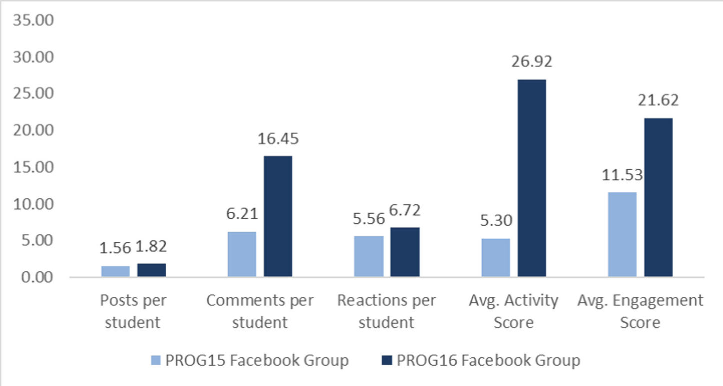


Fig. 5. Per student contribution (posts and comments) and collaboration (comments and reactions) within PROG15 and PROG16 FB groups

The increase of all FB Group metrics (students' Posts, Comments, Reactions, etc.) from PROG15 to PROG16 is depicted in Fig. 5, with PROG16 Comments and Average Activity score demonstrating the greater increase.

Contrary to the observed increase in all PROG16 FB Group metrics during the second research cycle, the PROG16 Udemy Q&A posts and comments demonstrated a decrease in comparison to PROG15 data. More specifically, the 24 active participants in PROG16 Udemy Q&A Forum uploaded 28 posts, that is 15 posts fewer than the 43

Table 3. Summary of UDEMY Q&A post related activities

UDEMY Q&A forum	PROG15	PROG15	Evolution
General			
Number of primary posts	53	209	294%
Number of words (in posts)	1,799	5,802	222.5%
Posts per student	1.56	1.82	17.3%
Number of comments	211	1875	789%
Number of words (in comments)	2,802	24,365	769.6%
Words per comment	13.27	12.99	−21.1%
Comments per student	6.21	16.45	164.9%
Comments per post	3.98	8.97	125.4%
Primary posts			
Primary posts commented	25	159	536%
% of primary commented posts	47.16%	76%	61.7%
Members			
Active members in the group	34	114	235%
Commenters	20	64	220%
Publishers	21	46	119%

posts uploaded in the Q&A forum of PROG15. Similarly, PROG16 students made 20 comments on the uploaded posts, that is 11 comments fewer compared to 31 comments of PROG15. At the same time, fewer students participated in the Udemy Q&A forum during the second research cycle (24 in PROG15 and 10 in PROG16) resulting to an increase on the per student average FB Group posts (2.80) and comments (2.0) on PROG16, compared to the per student average of PROG15 posts (1.56) and comments (1.29), as shown in Table 3 and Fig. 6.

The 28 posts that the 10 active participants uploaded on PROG16 Udemy Q&A forum contained on average 38.78 words, almost 5 words less than the average PROG15 post which contained 42.6 words. PROG16 students contributed with their Udemy Q&A posts 1,086 words to the course content, while PROG15 students 1,834 words.

Apart from their posts, students also contributed to course content with their comments. More specifically, PROG16 students contributed to course content 396 words, contained in the 20 comments they made either on primary posts or on other comments existing on the Udemy Q&A, while PROG15 students contributed to their course 513 words, contained in 31 comments.

The increase in the average number of posts and comments students uploaded on PROG16's Udemy Q&A forum is depicted in Fig. 6.

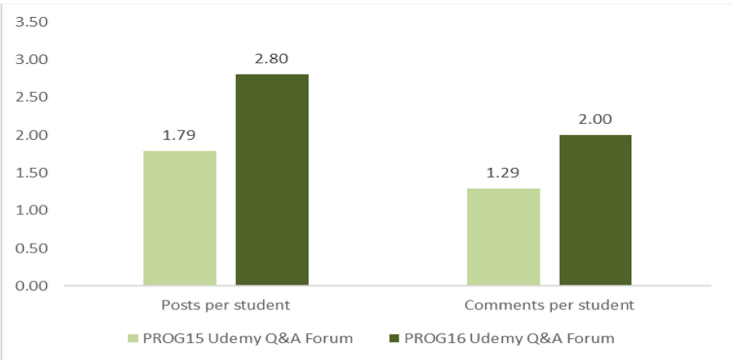


Fig. 6. Per student contribution (posts and comments) and collaboration (comments) within PROG15 and PROG16 Udemy Q&A forums

Figure 7 presents in a comparative way, the per students average of PROG15 and PROG16 Posts and Comments uploaded on Udemy Q&A and FB Groups giving us the ability to make comparisons into two different directions:

- Udemy Q&A vs FB Group post and comments
- PROG15 vs PROG16 posts and comments

All active students who participated in PROG15 and PROG16 collaboration platforms uploaded on average slightly more posts on Udemy Q&A forum and significantly more comments on the FB groups. In other words, the "average PROG15 and

PROG16 student" slightly preferred to use Udemy Q&A forum for uploading a post and very much preferred to use the FB group for making a comment.

On the other hand, the "average PROG16 student" uploaded more posts and comments in comparison to the "average PROG15 student" both on FB group and Udemy Q&A forum. This overall increase in PROG16 posts and comments can be interrelated with the 9 pre-scheduled FB meetings, which resulted to a significant number of posts and comments and developed a strong sense of community among participants.

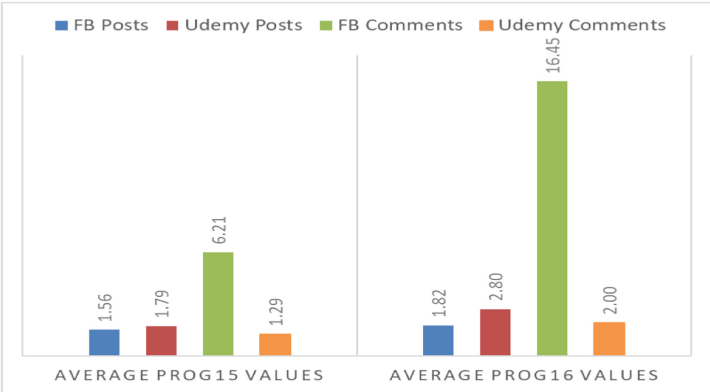


Fig. 7. PROG15&16 per student average FB & Udemy Posts and Comments

According to Grytics, the most popular day for connecting into FB group is the pre-scheduled online meetings day (Thursday) and its next (Friday), while the most popular hours for visiting the FB group are the hours around the pre-scheduled meetings hours (around 21:00) (Fig. 8).

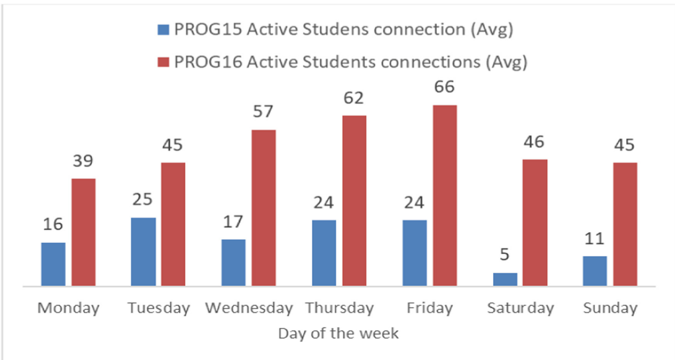


Fig. 8. Distribution of active PROG15 and PROG16 students on week days.

A quite interesting outcome which can be appointed to the 9 pre-scheduled FB meeting is that PROG16 students' connections to the FB group demonstrated a smoother distribution compared to PROG15 FB group connections both concerning (a) the hours of the day and (b) the week days. For example more than 40 students connect to the PROG16 FB group at least once every day (even on Saturdays and Sundays) in order to communicate or just to take a look on what's going on in this strong collaborative community (Fig. 9).

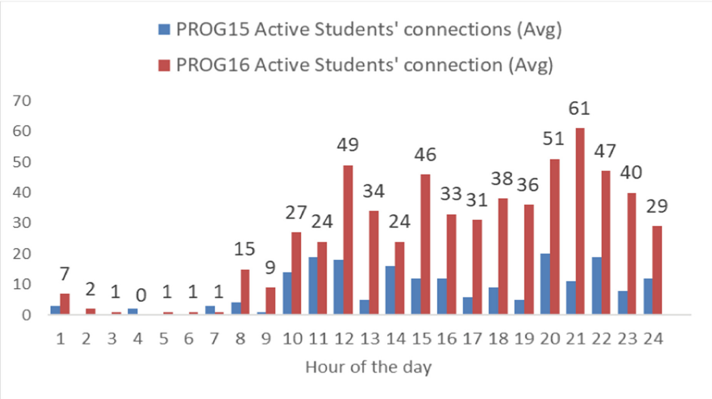
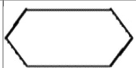


Fig. 9. Distribution of active PROG15 and PROG16 students on day hours

Aiming to identify the communication style and the dynamics of collaboration, interaction and content contribution we conducted a qualitative content analysis on some of the most interacted posts and comments on both FB and Udemy platforms together with an analysis of commenters' reaction time. Some representative examples are provided and discussed bellow.

On the 24th of May 2015, Student-1 posed a question at 21:34 on the PROG15 FB group. Two minutes later he received an answer by Student-2 and two minutes later a third student was involved on the conversation asking Student-2 to upload an example. The whole interaction consisted of the initial post and 10 comments, lasted 8 min (less than two minutes per comment) and ended when student-2 provided a concrete answer to the posed question (a screen-shot from the school book) and Student-1 thanked him.

Student_1, 21:34	Hey guys, how do you represent the Case command in a flow chart?
Student_2, 21:36	Polygon (with 6 angles)
Student_2, 21:37	
Student_3, 21:38	Upload an example if you can…

(*continued*)

(*continued*)

Student_1, 21:39	Yes, upload an example
Student_2, 21:39	Do you have the school book?
Student_1, 21:40	Yes, but why?
Student_3, 21:41	I face some difficulties with flow charts and Im trying to cope with them during these last days.
Student_2, 21:41	Here you are… 
Student_2: 21:42	Good for you, you are doing what you are supposed to do ☺[refers to the comment of Student_3 made at 21:41]
Student_1: 21:42	Aaaaaa, OK my friend, thanks

The content analysis of the above post and comments, together with the analysis of the representative most commented FB Group posts, revealed that students utilized for their communication within the context of FB Groups, quite informal, friendly, humorous, warm and relaxed language, mood and style of writing. To this extend many emotion icons and punctuation symbols accompanied students' posts and comments.

Furthermore, the content analysis identified a strong sense of belonging to the same cohort and genuine solidarity among students rather than competitiveness and rivalry. This is quite impressive taking into consideration that few days later the same students that helped and supported their fellow students within MOOCs' FB Group would compete each other in national exams for entering Greek higher education.

Compatible to the overall positive FB Group atmosphere was a student's query, on the 27th of May 2016, to keep the Group "open" and active for the other examined course in national exams (networks). The following conversation started on 27/05/2017 at 20:57, involved 7 students and the instructor, included 10 comments with the last made at 21:38. The commenters' speed is quite impressive.

Student_1, 20:57	Will this FB group remain open for networks too?
Student_2, 20:58	I vote yes
Student_3, 21:01	If it's OK with the instructor
Student_4, 21:03	I had the same question, I hope it will be OK for the instructor
Student_5, 21:09	I wish…
Student_6, 21:12	I wish too…
Instructor, 21:22	Student_1, what a great idea, yes of course!!!
Student_3, 21:23	Thanks a lot
Student_4, 21:04	Many, many thanks
Student_1, 21:05	Thanks sir!!!
Student_7, 21:38	❤❤

4 Discussion and Conclusions

This paper attempted to investigate the role that an open Facebook group can play as a complementary communication and collaboration platform in a K-12 computer programming MOOC. In this respect, PROG15 and PROG16 participants' behavior, contribution, collaboration and interaction within the context of (a) the on-site Udemy forum and (b) the open Facebook group were observed, recorded and comparatively analyzed.

PROG15 and PROG16 students contributed to the content of the course by uploading either their primary posts on both platforms (Udemy and FB group) or by commenting on other students' primary posts and comments. Students' comments and reactions (FB likes) on already uploaded content by their fellow-students, were a means of collaboration and interaction among students and the instructor.

Our comparative analysis of students' behavior within Udemy Q&A forum and Facebook group clearly showed that, in absolute numbers, more students enrolled, more posts were uploaded and more comments were made on the open Facebook group. On average, PROG15 and PROG16 students uploaded almost the same number of posts on both platforms, but students made significantly more comments in Facebook group than in Udemy Q&A forum. So, when the comparison came to the level of interaction and collaboration, Facebook seemed to be a far more attractive place for PROG15 and PROG16 students to get involved in conversations by commenting on other students' primary posts or comments.

In this respect, Facebook groups were proven especially beneficial for PROG15 and PROG16 students since they provided a familiar and at the same time effective and efficient environment for engagement with learning resources that other students uploaded on the Facebook groups and in discussion threads that other students started, supporting and promoting this way the development of a strong collaborative learning community. Additionally, the high degree of familiarity that PROG15 and PROG16 students had with Facebook platform's communication and collaboration features (posts, comments, reactions, etc.) made it an effective and easy to use communication and collaboration learning environment. Additionally, its widespread and ubiquitous use through mobile devices allowed easy and fast communication and collaboration among students and the instructor.

The content analysis of representative, most commented FB group posts, revealed a friendly, warm and relaxed mood within the context of the Facebook group, together with a quite impressive sense of belonging to the same cohort and genuine solidarity among students, despite the fact that these same students in a few days would compete with each other on the Greek national exams for entering higher education.

Additionally, our research found strong indications that the utilization of prescheduled, weekly on-line FB group meetings with the participation of the instructor in a supportive role, results in a more active, strong and bonded learning community.

Taking into consideration the above conclusions, we can claim that the utilization of social media environments like Facebook as a complementary communication and collaboration platform for K-12 MOOCs, under a set of prerequisites identified in this work, may support the collaborative learning communities for the next generation of

MOOCs. At the same time, further research efforts are required in order to maximize the benefits and minimize the risks of this quite promising combination of social media and MOOCs.

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To What Extent Is the Use of Interaction Models as Design Patterns Supported by Current e-Learning Authoring Tools? A Comparative Analysis

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Abstract. This paper focuses on the evaluation of the support of Interaction Models (IMs) as Design Patterns (DP) for the development of e-learning content using authoring tools. First, the Design Pattern and Interaction Models concepts are presented and the discussion of their significance for the development of engaging e-learning content follows. Then a comparative analysis of authoring tools is presented concerning the support of the implementation of Interaction Models though specific trial cases. The authors tried to implement the same interaction model using different authoring tools, without coding, to compare its feasibility and the difficulties that emerged. The comparison reveals that, even state of the art authoring tools, do not support, to a satisfactory extent, the implementation of models of higher interactivity without coding. The gap among IMs and authoring tools sets difficulties to content developers and rises risks for the quality of the authored learning material. The paper is of interest to developers of authoring tools as well as for the specification of training requirements of e-learning content developers.

Keywords: e-Learning · Interaction Models · Design Patterns · Authoring tools · Rapid e-learning

1 Introduction

Depending on the context in which it was applied (general education or professional training) from the moment of its appearance, e-Learning received different definitions. In the wider education community, e-Learning embraces "a diverse range of practices, technologies, and theoretical positions" [1]. E-Learning focuses not only on online contexts but includes "the full range of computer-based learning platforms and delivery methods, genres, formats and media such as multimedia, educational programming, simulations, games and the use of new media on fixed and mobile platforms across all discipline areas" [1]. In other words, e-Learning is a combination of different methods, structures and networked electronic tools orchestrated into systems that promote learning [2]. Regardless of its definition, the main purpose of e-Learning in the professional training domain is "to build job-transferable knowledge and skills linked to

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organizational performance or to help individuals achieve personal learning goals" [3]. Regardless of the domain of application, a prevalent challenge e-Learning faces concerns the building of lessons compatible with human learning processes, so that learners are not just passive recipients of rewards or punishments [3], but active collaborators that engage in the construction of knowledge.

To support digital content development for e-Learning, without computer programming skills, several authoring tools are available to designers, enabling them to compose multimedia and interaction in professional learning content [4, 5]. E-learning content developed using authoring tools is often characterized by low interactivity and many call e-learning applications as "page turners" that push information to the user and thus replicate a poor pedagogy which is based on the hypotheses that knowledge is transferred from the screen to the user [6]. E-learning courses should shape the interaction of the user with the content, to help the former construct knowledge through a variety of modern learning methods. To support e-learning designers achieve this goal, Interaction Models (IMs) were proposed as Design Patterns (DP) for easy implementation of best practices [7–9]. What kinds of IMs are integrated in authoring tools and how easy it is for the educator-designer to use them for the creation of really engaging e-learning material without coding, is a leading question for this research. Specifically, it is examined how current authoring tools support IMs for the creation of engaging learning activities. In the rest of the paper, the theoretical framework concerning learning design, rapid e-learning, authoring tools and IMs is presented first, then the process of IM's support estimation, by the authoring tools, is described by comparing examples using different tools, and, finally, the results of the research are discussed.

2 Theoretical Framework

2.1 Learning Design, e-Learning and Design Patterns

"Learning design is a representation of teaching and learning practice documented in some notational form so that it can serve as a model or template adaptable by a teacher to suit his/her context" [10]. In other words, learning design describes formally a prescribed learning experience to which the learners are exposed. Despite the differences in learning goals and learners' needs, it was noticed that many learning designs had similarities in their structure. The study of learning designs for e-learning and the generalization of the most successful ones lead to the formation of DPs [8]. Patterns have a common structure, but they do not emphasize on details, offering designers the flexibility to be creative [7, 8, 11]. Educational designers instantiate DPs in specific learning situations and thus achieve best practices from other cases. DPs allow designers, whether experienced or not, to develop e-learning content following reusable and easily modified scenarios that represent known effective practices.

2.2 Rapid e-Learning Methodology

Even though the use of design patterns facilitates the learning design process, the development of the e-learning content in software form remained a tedious and expensive part of the whole enterprise. Facing this situation, the e-learning industry borrowed ideas from the rapid software development approach to lower the cost and overcome the technological skill obstacles for e-learning content development formulating the Rapid E-learning methodology. Rapid e-Learning is all about software that *"empowers anyone to create e-learning without prerequisite programming skills"* [12], as it involves a wide variety of authoring tools of different features and capabilities from which the designer can choose the one that suits best his/hers needs and design his/hers own e-Learning lesson [5, 13]. These tools *"accelerate and simplify the development process which means that editing and updating content can be done quickly and painlessly"* [14]. Rapid e-learning approach provides a first operational version of the final program in a short while, thus ensuring the continuous interaction and involvement of educational designers for the processing, revision and improvement of the produced material until its final and complete form [15].

2.3 Authoring Tools

Authoring tools are *"software tools that enable instructional designers, educators, teachers and learners to design interactive multimedia and hypermedia learning environments without knowledge of programming languages"* [16]. They support a wide variety of media, such as text, graphics, video, audio and most of them include assessments and test features [4], making it possible for designers to *"repurpose digitized elements or learning objects from an existing course for reuse in a new one"* [4]. In other words, an authoring tool is a simplified programming application that includes pre-installed elements that facilitate the development of interactive multimedia and a point-and-click user interface that activates these elements [16]. An important criterion for choosing the right authoring tool is the category to which it belongs. There are two categories: (a) form-based authoring and (b) free-form authoring [12]. Form-based authoring tools allow the designer to add media to a form and then publish it. There are different forms for different types of interaction and in a few minutes the designer can achieve the desired result. An example of form-based authoring tool is Articulate Engage, which is part of the Articulate Suite. Free-form authoring tools, on the other hand, offer more flexibility to the designer to create on a blank page, provided he/she knows how to use them. PowerPoint, available in Microsoft Office Suite, is one of the most popular free-form authoring tools. Authoring tools empower the e-learning content designer and developer but also shape and limit their possibilities to the available conceptual model of the tool. Many authoring tools permit the expansion of their preconstructed functionality, using scripting programming languages and coding. Using coding, the power users of authoring tools can make more than the predefined learning interactions templates of the tool permit. This makes coding a still significant skill for e-learning designers and developers. In our comparison, we ignore this possibility and compare the tools according to their functionality without coding.

2.4 Interaction Models

Most of the authoring tools available, come with pre-constructed generalized interactive learning object types that help the development of engaging e-learning material.

For example, many authoring tools offer templates for the specification of single questions and/or complete questionnaires, some of them offer templates for the definition of simple learning objects such as memory games, image mapping, etc. All these interactive learning object types that are generalized patterns of the interaction of the user with the learning material, are formally defined and referred using the term Interaction Models. An Interaction Model is a generalized pattern of interaction of the user/learner to the digital content that is formally defined, and that can be instantiated as specific learning objects in the context of an e-learning course. It is obvious that Interaction Models constitute reusable Design Patterns that facilitate the design of engaging e-learning using Interactive Learning Objects as building blocks. An extended well documented collection of Interaction Models, independent from specific authoring tools, is described by Schone [6] (Table 1). For an experience to be engaging, the learner must be: (a) faced with challenge, (b) called upon to make decisions, (c) allowed to search and make mistakes without being punished and (d) have fun [6]. Thus, a sensory stimulus is required that causes the interest of the individual to discover the content, through meaningful interactions and playful elements. Interactivity is *"a cyclic process between two or more active agents in which each agent alternately listens, thinks, and speaks"* [17]. Schone [6] defines interactivity as a learning activity where the learner is presented with a problem or scenario and must work to achieve a goal. When these scenarios are based on issues that concern the individual in his or her daily routine, then higher engagement can be achieved. Schone [6] classifies interaction models according to their interactivity levels: (a) Passive, where the learner is only the receiver of information, whether it is text, graphics, videos, or charts, and interacts only by using navigation buttons, (b) Limited interaction, where the learner makes responses to simple exercises, such as multiple-choice quizzes or interactive animations, (c) Complex interaction, where the learner is prompted to fill text entry boxes and interact with graphics or simulations to see the overall impact of his/her intervention to a process, and (d) Real-time interaction, where the learner is engaged in a real-life scenario or simulation and interacts with other learners and a facilitator in a collaborative environment.

Schone's Interaction Models (Table 1) are considered useful general types of interactive learning objects as building blocks for engaging e-learning content. The use of IMs concept facilitates the production of engaging e-learning content, because they concentrate effective experience of e-learning designers and make the transfer of best practices easier. All these come to reality more easily if the authoring tools support their implementation without coding. In other words, authoring tools design should support IM implementation and their quality could be evaluated in the base of high interactivity IM templates support.

Modern social-constructivist learning theories claim that e-learning takes place during social interaction between learners where knowledge is shared and built through the computer, which is the primary means of communication. This model of educational approach is called Computer-Supported Collaborative Learning – CSCL. In this model, collaboration scripts are designed to engage students in social and cognitive activities that happen either rarely or not at all [18]. However, these computer-supported scripts are usually restrained to a specific learning platform and context and there is an attempt to *"formalize them to foster reusability and portability of*

Table 1. Schone's interaction models

No	Interaction model	Interactivity level
1	Scattered steps	2
2	Myth or fact	2
3	Interactive timelines	2
4	Acronyms or alphabet fill-ins	2
5	Order of importance	2
6	Find the mismatched/stand-out item	2
7	Story-based questions	2, 3
8	Simple game-based interaction – e.g. crossword/memory	2, 3
9	Exploring a complex process or procedure	2, 3
10	A customer's perspective	2, 3
11	Incomplete stories	2, 3
12	What's wrong with this picture?	2, 3
13	Before and after or old way vs new way	2, 3
14	Teach back (a.k.a train the new person)	2, 3
15	Using an agent or character	2, 3
16	Scavenger hunt	2, 3
17	Read/watch and reflect	2, 3, 4
18	Fix it!	2, 3, 4
19	Did I do this correctly?	2, 3, 4
20	Story-based adventure	2, 3, 4
21	Branching stories	2, 3, 4
22	Challenge and response	2, 3, 4
23	Interactive spreadsheets	2, 3, 4
24	Virtual products/virtual labs	2, 3, 4
25	Solving a mystery/investigating a scenario	2, 3, 4

standardized scripts" [18]. The scope IM of Table 1 do not cover CSCL scripts and the same stands for most of the rapid e-learning authoring tools. CSCL scripts are supported by learning design environments (e.g. LAMS) but their study as e-learning design patterns is not relevant in this paper which focuses on e-learning authoring tools. In this paper we attempt such a comparison to map the gap among the IM and the current e-learning authoring tools functionality.

3 Designing e-Learning Content Using Interaction Models

For this study, the methodology applied included comparative case studies [19], in which Schone's interaction models were used as design patterns for the development of interactive digital learning objects aimed to primary school children for various learning subjects. The aim of the evaluation is to map the gap between IMs and their support from the authoring tools that are accessible to formal education teachers or e-training designers of low technology profile. The result could be useful for the design of teachers' training as well as for the authoring tools' development. The following two authoring tools that support the creation of e-Learning courses were selected: MS PowerPoint v.365 and Articulate Studio v.13. The Articulate Studio was chosen among other six, similar in their conceptual model, design and functionality, slide based authoring tools (CourseLab, Lectora 16, Chatmapper, Microsoft Learning Content Development System (LCDS), Raptivity and Sankoré). Articulate Studio, in other words, was preferred as it is believed that it is a tool that limits the difficulties encountered among the others to a higher degree, as it is a state-of-the-art, high-end authoring tool which has integrated IMs that designers can use without the need of specific knowledge. PowerPoint was selected as the multimedia presentation tool that probably most teachers are familiar with. Both tools are free form, use slides for the logical organization of the material, allow the use of multimedia and support hyperlinks for bypassing the linear layout of the slides [13]. Articulate seems to have invested on PowerPoint's interface and large number of users, thus being compatible with it and enhanced with tools for e-Learning. PowerPoint remains a pioneer presentation tool, but to meet the needs of creating e-Learning material, it is based on additional systems, such as the OfficeMix add-on.

For the comparison, we chose to implement specific instantiations of the same IM to both authoring tools. These trial cases, based on indicative learning activities, will reveal the limits of the tools and the difficulties the author faces. Concerning the content of each trial case, modules from the Greek primary school curriculum were selected with an increasing degree of difficulty, to respond to the interaction levels that characterize Schone's interaction models. Primary education content was selected for the author to be familiar with the subject, as a licensed primary education teacher, so her subject matter expertise level will not affect the result negatively. The difficulties and obstacles identified in the effort of each IM implementation were recorded for each tool separately, to subsequently formulate the results obtained. Due to paper limitations, only three indicative trial cases of different interaction models will be presented and compared in detail. The trials selected are those that reveal the most interesting support gaps and give evidence about the difficulties of IM implementation using the current Authoring Tools.

3.1 PowerPoint and Articulate Studio Examples

The first example concerns a trial case of IM No. 3: Interactive Timelines. This case is about creating a timeline of events where a learner can navigate to find about milestones and events by clicking on dates or images. Odysseus Journey, as included in History course for the third grade of Greek Primary Education, was selected as the learning subject (Fig. 1). For the development of a corresponding learning object for this activity in PowerPoint, there was a map of the journey created and pins were added next to the names of each place visited, acting as hyperlinks that, when clicked, transfer the learner to a new slide containing more information about the place. Audio narration was added besides text and images and a small compass in every slide acted also as a hyperlink that facilitated navigation among the slides and the map. In this activity there was no need for assessment, as it concerns exploration and search of information.

To create the same activity with Articulate and specifically Articulate Engage, we used the preconstructed and reusable timeline interaction model that was offered by the tool. This model allows the designer to add text and audio to each bullet on the arrows. However, in Articulate Engage there were limitations on images, as only one image could be added on each slide and a map could not be used as a starting point. To overcome this obstacle, a map was added in the intro slide, which could only be magnified. Also, when choosing fast among the bullets, the sound started simultaneously, for all the bullets selected. Lastly, the size of the slide is prefixed on 4:3 scale, thus limiting the possibilities of design and creation.

Fig. 1. Interaction model no. 3, developed with PowerPoint (up) and Articulate Engage (down).

IM No. 3 was completed (COMP) in both authoring tools. However, PowerPoint offered more flexibility to the designer to create a more fascinating visual experience, whereas Articulate Engage was more limited as the template provided was restricted to one image for each bullet on the timeline (Fig. 1). Excluding this factor, the IM allows reusability for both authoring tools, with PowerPoint having a more complicated structure due to the hyperlinks used (Table 2).

Second trial case is IM No. 9: Exploring a complex process or procedure. In this case the learner must move the mouse over different parts of a diagram to find information about the process shown. Healthy diet was chosen as the learning subject content for this activity. To create the learning activity in PowerPoint, a pyramid SmartArt was added, and the first slide was multiplied as many times as the pyramid levels (five). Then, each slide was supplemented with more information and audio about the level it represented, and invisible boxes in the first slide were acting as hyperlinks that, when hovering the mouse over them, the learner was transferred instantly to the corresponding slide (Fig. 2). In this activity no assessment is required, and it can be fully completed with PowerPoint, but requires attention to the position of the images and shapes, so that the desired effect can be achieved.

Fig. 2. Interactive model no. 9 designed with PowerPoint (up) and Articulate Engage (down).

In Articulate Engage, the same activity was created by using the pyramid template available and just inserting the information and an image for each level. When clicking on each level, a small pop-up window appeared, showing information and a relevant image. However, there were limitations because the designer was not able to add images on the block levels but could only add text, change the colors of the levels and divide them in smaller blocks. Audio was supplied in both authoring tools but not required.

IM No. 9 was completed (COMP) in both authoring tools without difficulties. The main differences are located on the visual result that emerged, as seen on Fig. 2. PowerPoint allows the designer to add more images on the canvas while Articulate Engage combines one image with text, limiting the creation options. Both tools can easily modify the content to reuse for another learning purpose.

The last example is a combination of four IMs (No. 7, 20, 21, 22) that were joined together, as they exhibited several similarities in their characteristics and they are based on the basic structure of a branching story. It is an adventure game based on storytelling with questions that challenge the learner to decide what is safer to do when walking home from school (Fig. 3). This activity was difficult to create in PowerPoint, as it contained many images, shapes and hyperlinks that, depending on the answer chosen, led to different slides and had a different outcome for the user. Feedback is given on every choice and there is no need for assessment, as the result leads to a positive or negative outcome. Creating the same IMs with Articulate Studio was quite a challenge. Articulate Presenter, as an add-on to PowerPoint, helped integrate quizzes or interactive ways of displaying information in the already configured PowerPoint presentation, however, none of these additional features could enhance the trial case or facilitate its design, leading to a very limited interaction.

IMs 7, 20, 21, 22 are completed (COMP) in PowerPoint mainly due to the use of hyperlinks that, when clicked, lead to a new slide or trigger a text-box containing information to continue the story. However, this requires a very complicated structure that prevents every reusability attempt. On the other hand, Articulate Studio, as an application that is not based on the design of branching stories, managed to integrate the IMs partially (PART), as hyperlinks and animations designed with PowerPoint, but refused to load when clicked.

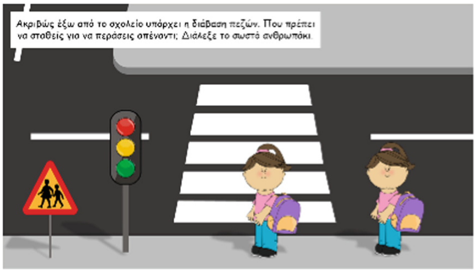

Fig. 3. Interaction models 7, 20, 21, 22 as created with PowerPoint.

4 Comparison and Results

In total, 18[1] trial cases were designed for each authoring tool. In PowerPoint, only 5 out of 18 IMs were totally completed (COMP), 12 out of 18 were partially completed (PART) and only one IM (23. Interactive Spreadsheets) was impossible to create in both of the two programs (IMP), as it required interactive spreadsheets, a function mainly provided in Excel. Articulate Studio predominates significantly by a total of 11 IMs completed out of 18 (Table 2), 5 out of 18 IMs partially completed and 2 out of 18 were impossible to complete. The main difficulties faced were located on:

1. *the drag-and-drop feature*: If it was available in PowerPoint, it would have contributed to the completion of three additional IMs (IM 1, 5 and 11). These IMs were more easily completed in Articulate Studio, as the drag-and-drop feature was already installed. For PowerPoint, this feature requires programming knowledge and, especially Visual Basic for Applications (VBA), a programming language that the targeted group of this research is not familiar with.

[1] Due to relevance in content, some interaction models were merged into one, leading to 18 trial cases created, rather than 25 different interaction models.

2. *the use of hyperlinks*, which played a significant role in the creation of the majority of the IMs in PowerPoint and especially those that required a higher interactivity level (IMs no. 10 and above), whereas hyperlinks were not available in Articulate Studio, leading to the weakness of Articulate Studio to implement IMs related to branching stories (IMs 7, 12, 15, 16, 18, 20, 21, 22, 24, 25).
3. *linear structure*, which, especially in PowerPoint, forced the user to follow a specific choice to move on the next step, e.g. in IM 1. Scattered Steps, the user must click on the first correct image of the process shown to move on the next slide and select the second correct image and so on, but if the user clicks on a wrong image, no transition takes place and only a "wrong" sound offers feedback, leading to a "compulsory" choice for the user. However, this IM created in Articulate Studio, was completed using the drag-and-drop feature available, allowing the user to arrange the images-objects in line and then evaluate his/her answer.
4. *reusability*: Articulate Studio includes a variety of pre-installed templates that make it easier to integrate IMs and use them again for a different purpose, whereas PowerPoint fails to create IMs that facilitate reusability, even though IMs can be created and completed in PowerPoint. For example, IMs based on storytelling, were completely integrated in PowerPoint, but due to the significant number of hyperlinks, it is difficult to use the same template for the creation of a new, different story.
5. *feedback and assessment:* Feedback and evaluation were not compulsory in IMs that were about seeking information (e.g. IMs 3, 9) but were important for IMs that required a score. Articulate Studio offers a collection of points that lead to a final score as well as the ability to re-take the activity, whereas PowerPoint can give feedback only through sounds that take place "on click", or objects containing information about the answer given. However, this leads to a combinatorial explosion, as there are many hyperlinks and animations combined that are quite difficult to create for the desired result.

In both tools, the design of the trial cases was relatively easy, regardless of the feasibility of completing them. In PowerPoint, 8 out of 18 IMs can be easily designed, whereas 4 needed more attention, due to the movements and hyperlinks. On the other hand, in Articulate Studio, although Articulate Presenter acts as a supplementary extension of PowerPoint and uses most of its utilities for the design, all IMs concerning branching stories failed to be completed because hyperlinks and animations triggered by click did not load.

It was observed that only automated animations were able to appear after the trial case was published. Moreover, as shown by the results, although a higher level of interaction is achieved mainly through Articulate Quizmaker and Engage, as they provide more functions for the creation of the IMs, they fail to integrate IMs of higher interactivity levels, and specially IMs that concern branching stories. It is important to mention here that Articulate Storyline, an authoring tool not examined in this research, was developed to address this disadvantage. PowerPoint, on the other hand, allows interaction only where the user is prompted to choose an answer, thus PowerPoint is more favored for activities that include branching stories. From the above, it appears that authoring tools fail to significantly integrate IMs, as they lack specific features that are considered important for the design of IMs.

Table 2. Authoring tools comparison

IM	PowerPoint		Articulate studio	
	Int.	Comments	Int.	Comments
1	PART	Linear structure, no drag-and-drop feature	COMP	Easy to create, reusability
2	PART	No feedback, combinatorial explosion	COMP	
3	COMP	Reusability	COMP	
4	PART	No assessment	IMP	No hyperlinks or template available
5	PART	No assessment, no drag-and-drop feature	COMP	Easy to create, reusability
6	COMP	Easy to create, reusability	COMP	
7/20/21/22	COMP	Difficult to create, no reusability	PART	Difficult to create, no hyperlinks
8	PART	Requires VBA	COMP	Easy to create, reusability
9	COMP	Easy to create, reusability	COMP	
10	COMP	Medium difficulty to create, no reusability	PART	Animations based on clicks do not load
11	PART	No assessment, requires VBA or drag-and-drop	COMP	Easy to create, reusability
12/18/24	PART	Requires simulation	PART	Requires simulation
13	PART	Created using OfficeMix, no assessment	COMP	Easy to create, reusability
14	PART	Medium difficulty to create, no reusability	COMP	
15/16/25	PART	Hyperlinks do not facilitate navigation, no inventory	PART	No hyperlinks, no inventory
17	PART	Created using OfficeMix, no assessment	PART	No feedback
19	PART	No assessment	COMP	Easy to create, reusability
23	IMP	Requires spreadsheets	IMP	Requires spreadsheets

IM: Interaction Model, Int: Integration, COMP: completed, PART: partially completed, IMP; impossible to complete

5 Summary-Discussion

From the IM's implementation, in the context of learning activities designed with PowerPoint and Articulate Studio, two well-known authoring tools, it appears that they cannot fully accomplish their support for the application of rapid e-learning methodology. Although IMs are considered important and there is an attempt to implement them in Authoring Tools, it seems that there is a significant number of IMs that are not supported and specially IMs of higher interactivity levels. Considering the Authoring Tools examined, PowerPoint lacks additional interactive features such as drag-and-drop or “text-entry”, requiring programming knowledge by the designer, and assessment methods, resulting in a significant number of IMs not being completed. It is worth emphasizing at this point that although Microsoft attempted to upgrade the functions provided in PowerPoint with the development of OfficeMix add-on, it seems that it is a tool for video-tutorials production, despite being a generic e-learning authoring tool. For example, there are quizzes that provide feedback, but cannot calculate score. Articulate Studio, on the other hand, is a more modern tool for designing educational activities. With the included programs, Articulate Quizmaker and Articulate Engage, it can achieve a highly interactive activity design, as the former provides a wide variety of pre-installed templates (true-false, multiple choice, drag-and-drop, etc.) and the latter facilitates the presentation of information in a more interactive way. Articulate Studio offers a more integrated educational design functionality than PowerPoint, while PowerPoint implements more easily IMs based on branching stories. In any case, the use of these two authoring tools largely depends on the target audience. More specifically, if it concerns:

1. *E-learning content developers training*: The tools should implement clearly the IMs, so the trainers could use them straightforward. A simple scripting language could make their adaptation and extension possible. If the target audience is IT students who want to specialize in educational design and technology to produce digital learning content, then it is recommended for them to learn some scripting language, such as JavaScript or HTML5, or some authoring tool or platform that supports game development.
2. *In service teachers’ training*: PowerPoint is preferred for IMs that are based on branching stories, while Articulate Studio for most IMs. Of course, a tool that supports the flexible implementation of IM will be preferable.
3. *Preservice teachers’ training*: Emphasis is given on instructional design and the supporting features of the authoring tool. PowerPoint can be used combined with a scripting programming language for the development of new IMs.

In addition, in any case, the authoring tools training should be combined with the theoretical framework of design patterns and rapid e-learning, but new IMs invention should be an option. Finally, due to the new technological environment created by mobile devices (tablets and smartphones) and the pedagogical model of portable learning, it is quite important that the authoring tools used must be improved accordingly so that they can support the production of educational material compatible with these portable devices.

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Current Trends in On-line Games for Teaching Programming Concepts to Primary School Students

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Abstract. In this paper current trends in online educational games for teaching programming concepts, or else computational thinking, to primary school students are analyzed. Specifically, several online games such as CodeMonkey, Getcoding, Kodable, Lightbot, Program Your Robot, Rapid Router and Run Marco are briefly presented. This is followed by a comparative analysis of important features both regarding the game mechanics and their educational aspects. Specifically, the following features are analyzed: the genre and the scenario of the game, game mechanics used for entertainment purposes, programming concepts/constructs supported, the support provided by the editor for implementing programs, testing and debugging facilities. Moreover, enhanced features, such as the support for creating on-line classrooms, monitoring students' progress and capabilities of creating new levels in the game are investigated. Conclusions and open-issues for further research in the field are presented.

Keywords: Educational games · Programming · Computational thinking · Online programming games

1 Introduction

Computer programming is considered by many researchers as an effective way to develop high level skills, such as problem solving, logical thinking, critical thinking, and computational thinking [1–3]. However, learning programming is not easy [4]. Programming concepts are abstract and the classic teaching approach that is based on presenting theoretically programming concepts and implementing number and symbol processing programs in professional programming environments does not motivate students in learning programming [5]. In order to overcome such difficulties various teaching approaches [6] have been proposed. Moreover, different types of educational programming environments have been proposed [7], such as: programming microworlds [8], flowchart-based programming environments [9] and more recently educational games [5, 10–13].

Using educational games in the teaching process can bring many benefits. Educational games incorporate an attractive and interactive learning context that motivates students for practicing with programming and provides them appropriate feedback,

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challenge and scaffolding [10–12, 14]. Several educational games for learning programming have been developed with promising results [15]. When dealing with primary school students, utilizing educational games for an introduction to programming concepts as a means of promoting Computational Thinking (CT) is considered even more important. Moreover, as Zaharija et al. [4] state, games can play an important role in teaching programming to young students, since the classic teaching approach is not appropriate for their age and does not help in dealing with difficulties such as the short attention span that characterizes them.

The main purpose of this paper is to review existing online educational games that aim to teach computer programming concepts to primary school students and present their main potential in an organized way.

In order to capture the potential of the games and achieve a more accurate comparative analysis, we searched for papers that describe or evaluate each game, studied its' webpage (if available) and finally played it in order to gain personal experience.

The rest of the paper is organized as follows: the next section presents briefly the main results of similar studies on games designed to teach basic programming concepts. Section 3 presents the main characteristics of seven educational games for teaching basic programming concepts, while Sect. 4 presents a review and comparative analysis of them. Section 5 discusses the results of the comparative analysis and finally, in Sect. 6 conclusions are drawn and proposals for further research are presented.

2 Relevant Work

Vahldick et al. [13] evaluated 40 games published in the last decade, which claim to teach introductory programming concepts. For each one of the games, they recorded the following elements: the type of the game, the platform on which it runs, the types of the activities it includes, the educational content it covers, as well as the programming languages it supports. They also recorded some features that are missing from the games and which could improve their effectiveness. Among these is the small number of programming languages supported by each game. In addition, they found that in most games the player is limited to write a program by arranging visual icons and not allowing him to write code in a real programming language as he progresses into the game.

Malliarakis et al. [3] based on a framework suggested by Becker [16], identified functionalities that should be supported by educational games in general and recorded the extent to which they are supported by ten educational games for computer programming. The comparative analysis of the games was based on the following features: *educational goals, scenario's space, related cases, framework* (educational content), *information resources, facilitating tools* (tools that students can use when they are trying to execute a task and that help them build new knowledge), *generic conditions* such as the location and type of the education to take place (e.g. offline, online, blended learning). Findings of this study reveal that the majority of the games compared seem to satisfy most of the characteristics to a satisfactory extent, but they teach fairly simple concepts and there are limited experimental studies and validations of them.

In another study Laporte and Zaman [14] identified 10 categories of young novice programmer problems, and examined how these were addressed in a set of 19 existing programming games. They found that problems that are specific to the programming domain such as, *mapping* and *problem solving strategies* or *writing correct syntax*, which were identified from the authors as components supporting the *programming process*, are problems that the majority of the games do not address to a large extent. On the other hand, problem categories such as *design*, *implementation* and *evaluation*, identified as *process components* which are issues that are common to other learning domains too, are addressed in a better way from the games investigated. Finally, problems associated with *attitude, motivation* and developing *mental models* are addressed to a satisfactory degree.

Combéfis et al. [1] reviewed the following seven educational online platforms or serious games: *Codecademy, Code Fights, Code Hunt, CodinGame, Initial Conditions, Leek Wars* and *Lightbot*. They found that all of them are visual games, interactive with keyboard or mouse, 2D and online. With the exception of *Leek Wars*, none of the other games supports collaboration, while the majority of them are designed for a single player.

In this paper, we focus on the comparative analysis of seven online games that aim to teach programming concepts to primary school students. These games, presented in Sect. 3, are as follows: *CodeMonkey, Getcoding, Kodable, Lightbot, Program Your Robot, Rapid Router* and *Run Marco*. After a literature review we managed to find only two empirical studies that focus on primary school students concerning the use of the educational game *Kodable* and three studies that refer to the games *Lightbot* and *Program Your Robot*, but their target group was higher education students. The findings of these studies are positive regarding the use of an educational game in the learning process and a summary of these findings is presented in [17]. Moreover, in [17] an empirical study aimed at investigating the effectiveness of *Run Marco* for teaching basic programming concepts to primary school students, as well as students' acceptance regarding its use in the learning process are presented.

3 On-line Games for Teaching Programming

This section introduces seven educational games designed to teach basic programming concepts to novice programmers. In this study we mainly focus on games that we believe that are suitable for primary school students. All the games are on-line games running on a web browser. However, some of them provide freely only some of their levels or features and require a subscription in order to have access to all of their levels.

3.1 CodeMonkey

CodeMonkey (https://www.playcodemonkey.com) is an online game that teaches basic programming concepts. It uses a real open-source programming language called *CoffeeScript* that compiles to *JavaScript*. In this game the player helps a monkey to retrieve her lost bananas from the bad gorilla who stole them. To do this, players must write lines of code in the right side of the screen in order to guide the monkey in the left side of the screen to catch all the bananas that make up a different puzzle at each level (Fig. 1).

Fig. 1. CodeMonkey. (Color figure online)

3.2 Getcoding

Getcoding (http://www.hepis.gr/getcoding) is another game that aims to teach basic programming concepts to novice programmers. In this game, the player guides the hero of the game (Thales or Irida) on a path formed by a grid of squares, to reach a destination block and collect a gold coin. The player programs the hero to move on the path using simple visual commands which can move the hero one square forward or to turn him 90° right or left (Fig. 2). As the player moves to the next levels of the game more complex commands are unlocked.

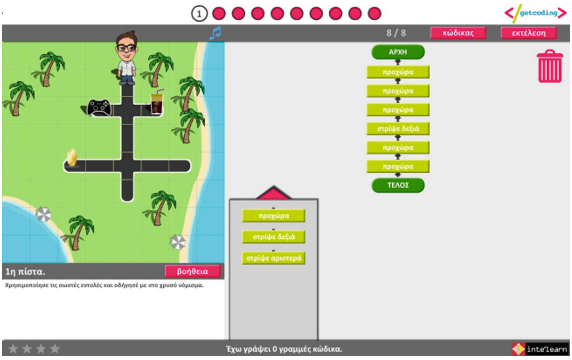

Fig. 2. Getcoding. (Color figure online)

3.3 Kodable

Kodable (https://www.kodable.com/) is another educational game for teaching basic programming concepts in kindergarten or elementary school students. The basic idea behind this game is that the *Faze family* has landed abnormally on the planet *Smeeborg* and begins exploring the planet. At the first levels of the game the player guides the *Fuzzes* through a series of linear mazes trying to collect at the same time up to 3 stars that are placed on various points on the mazes (Fig. 3). In order to achieve this, the player drags and drops simple commands such as *go up, down, left* and *right*, in a specially designed editor.

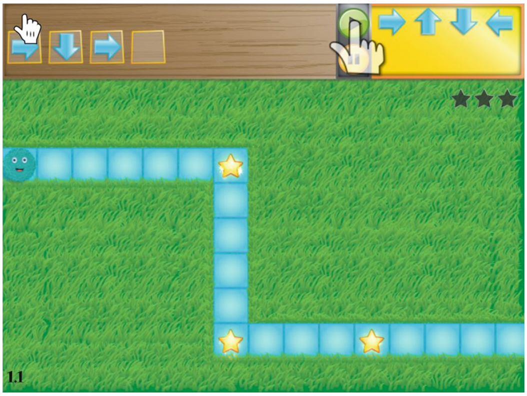

Fig. 3. Kodable. (Color figure online)

In the second section of the game, which is the planet *Asteroidia*, the player attempts to clean a range of asteroids placed on the right of the screen by throwing colored fuzz balls from the left side of the screen. Finally, in the last section of the game, named the *Bug World*, the players protect the *Fuzz family* from the coming mud, which is fired by the enemies. For this purpose, players build various new towers that best fit their defensive need, which are essentially objects from the class *tower*.

3.4 Lightbot 2.0

Lightbot 2.0 (http://armorgames.com/play/6061/light-bot-20) is an online flash game designed by Danny Yaroslavski that introduces the player into basic programming concepts such as *sequencing, functions, recursive loops* and *conditionals*. The player controls a small robot in a fantastic world of square tiles, representing a puzzle, in order to light up all the blue tiles. To achieve this, the player writes a small program dragging icons from a toolbar and dropping them in an area of empty slots. Icons represent commands like *"move forward", "turn left", "jump"*, etc. As the player moves to the next levels of the game, the puzzles become more complicated, and more sophisticated combinations of commands are needed in order to achieve the goal of the level. Figure 4 shows the environment of the game where the robot and its fantastic world are shown on the left and the program representing the behavior of the robot is shown on the right.

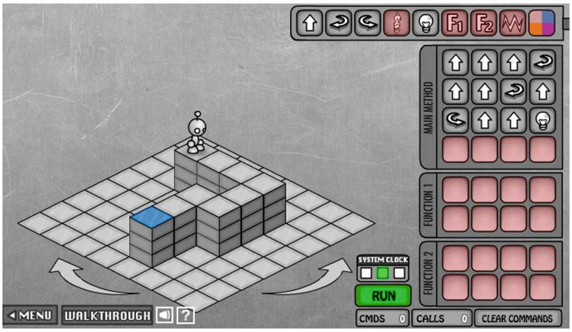

Fig. 4. Lightbot 2.0. (Color figure online)

Two distinct versions of *Ligthbot* which differ from version 2.0 - in terms of the topics covered - are *Lightbot 1.0* and *Lightbot Hour of Code*.

3.5 Program Your Robot

Program Your Robot is an online flash game developed by Kazimoglou et al. [10, 11] as an academic project. The game supports the acquisition of CT skills (such as algorithm building, debugging and simulation) and simultaneously introduces the player to basic programming concepts [10, 11]. In this game, the player assists a robot to escape from a series of platforms that make up the different levels of the game, leading the robot to a specific escape point that will lead it to the next platform. In order to achieve this, the player drags icons from a toolbox and places them in an appropriate order over an area of empty slots. These icons represent specific commands for the robot such as *"move forward"*, *"turn right"*, *"turn left"*, etc. As the player moves to the next levels, the platforms become more complicated, increasing the game's complexity. Figure 5 shows the game's environment where the robot and the platform are shown on the left side, while the program representing the behavior of the robot is shown on the right side.

Fig. 5. Program Your Robot. (Color figure online)

3.6 Rapid Router

Rapid Router (https://www.codeforlife.education/) is an online free game that aims to teach basic programming concepts to novices. The game was created to support English primary school teachers in 2014, the year that the computer programming course was integrated into the new UK curriculum. The game implements a scenario where the player drives a delivery van on a road, in order to reach a destination point and complete the delivery. The road is divided into sections and there are bends and lanterns along the way, so the player has to program the "van" to behave appropriately in every case. The player programs the van to move on the road, joining visual blocks that represent special commands, one below the other, just like in Scratch. Figure 6 shows the environment of the game with the van and the road on the right side, while on the left side we can see the program that has been written to drive the van in its' destination.

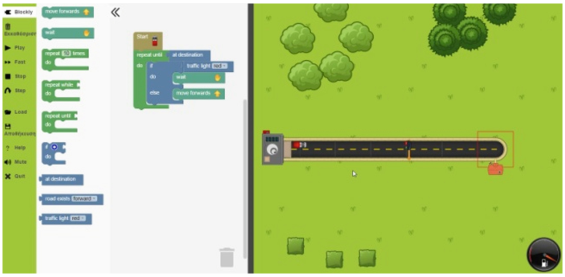

Fig. 6. Rapid Router. (Color figure online)

3.7 Run Marco

Run Marco (https://www.allcancode.com/web) (Fig. 7) is an educational game that aims to teach the player basic programming concepts, such as sequence commands, iteration and conditions. Players are asked to help *Marco* or *Sophia* - the main character - who is lost in the jungle, so he/she can find his (her) friends again. For this purpose, at

Fig. 7. Run Marco. (Color figure online)

each level of the game, the players give the appropriate commands to *Marco*, guiding him on a path. In particular, the players *"drag and drop"* visual blocks that represent commands such as *"step forward"*, forming a set of commands. When pressing the *"run"* button the players can see how *"Marco"* reacts executing the commands written for him.

At the time of utilizing *Run Marco* in the pilot study presented in [17], the teaching platform was giving us access to various tools, such as *class management*, the ability to implement *lesson plans*, as well as *authoring tools* to adapt them to our class needs. The platform allowed the creation of new activities, the design of personal lesson plans and their implementation with our own *private e-class*. It is obvious that such tools can be very useful to an instructor in order to create his/her own personal curricula adapted to the needs of his/her class. Another useful feature was the *dashboard* which allowed monitoring students' progress in the game in real time. We must note, however, that at the time of writing this paper the game does not allow the use of these authoring tools.

4 Comparative Analysis

4.1 Scenario

All the games utilize a fantastic scenario in which the player programs the movement of a character (like a robot, a turtle, a van, etc.) in a simulated world, in order to reach a destination. In addition, in *Kodable*, the scenario of the game changes after some levels, with the player taking on different missions, such as building defense towers or destroying some asteroids. In *Getcoding*, *Lightbot Hour of Code* and *Run Marco* there is a choice between two available avatars, which makes it more possible for the player to identify with the main character in the game, while in *Kodable* the player can change or design a new avatar, as he progresses in the game. The selection of *Marco* or *Sophia* in *Run Marco*, for example, gives young boys and girls the chance to easier identify with the character that they control within the game. In *CodeMonkey, Kodable* and *Program Your Robot*, the player collects some objects in his path. Furthermore, in *CodeMonkey, Lightbot 2.0, Rapid Router* and *Run Marco* there are some obstacles, such as lanterns, traps or blocks, which the character should avoid, in order to reach his destination. *Program Your Robot* and *Kodable*, are the only games which include enemies that the player has to avoid or to defense. With the exception of *CodeMonkey* where the player in some tasks must fix the errors in a given program and *Kodable* where the player assigns values to variables in some tasks, creates new objects or modifies objects' properties, none of the rest games include a wide variety of activities. Specifically, the activities remain within the domain of designing an algorithm, in order to direct a hero to a specific point.

4.2 Game Mechanics

Almost all the games presented in this study are classified as puzzle games, with *Kodable* also supporting other types of activities besides puzzles. All of them provide some kind of support to the player to solve the activities. *Lightbot 2.0, Run Marco,* *CodeMonkey* and *Kodable* have tutorial levels that support the player whenever a new programming concept is introduced, providing a step-by-step guidance or making available only the code constructs required for solving the specific level. *Rapid Router* and *CodeMonkey* display informational messages before running an activity, providing the player with significant support. In addition, the games *Program Your Robot* and *Getcoding* provide videos, that explain the use of the graphical user interface, the rules of the game and the functionality of the programming structures.

Only the games *CodeMonkey* and *Program Your Robot* reward the player with a total score for his performance, while *Rapid Router* scores each activity individually. *CodeMonkey* requires the player to have an account in order to see his total score. *CodeMonkey*, *Getcoding*, *Kodable*, *Rapid Router* and *Run Marco* reward the player after the successful completion of each activity displaying appropriate messages. *Lightbot 2.0* also somewhat rewards the player counting the number of commands used for a solution. Additionally, *CodeMonkey*, *Getcoding* and *Program Your Robot* reward players through an integrated reward system of achievements [18]. With the exception of *Lightbot 2.0* all the other games encourage the player to give a better solution, rewarding him in this case e.g. with a better score or with appropriate messages.

4.3 Topics – Programming Concepts

Table 1 presents the programming concepts covered by each one of the games presented in this study. *CodeMonkey* is the only game that does not support *if statements* (in its free version which is presented in this study), while *Lightbot 2.0* does not support *iterative structures*, proposing the use of *recursion* instead. The games *Getcoding*, *Rapid Router* and *Run Marco* incorporate activities with *nested if* and *loops* with an unknown number of iterations (*do..while* or *Repeat..until*). *Functions* are supported in *CodeMonkey, Kodable, Lightbot 2.0, Program Your Robot* and *Rapid Router*. The games *CodeMonkey*, *Kodable* and *Rapid Router* also support the concept of *object-oriented programming*, while *Kodable* and *Rapid Router* are the only games that use *variables*. Finally, *Run Marco* will incorporate all the programming concepts presented in Table 1 in a future version according to its designers.

CodeMonkey, *Kodable* and *Rapid Router* are embedded into a broader learning platform, which provides extensive support through a series of ready-made lesson plans that include activities based on game philosophy. Also, *Getcoding* is accompanied by a book [19] with theory and exercises inseparably connected to the game.

4.4 Programming Language and Editor

All the games incorporate a programming editor that allows the player to write a program. In Kodable, *Lightbot 2.0* and *Program Your Robot* the player *"drags and drops"* from a toolbar visual icons (commands) in an area of slots eliminating in this way, the syntax errors [13]. The area of slots is limited and in some activities only a few number of slots are available, forcing this way the player to write more efficient programs or either use specific programming concepts such as functions, recursive calls etc. Additionally, in *Kodable* the player has the ability to modify the avatar's properties (for example, the body color, the eye color, the type of mouth etc.) using JavaScript,

Table 1. Programming concepts.

Topics	Games						
	CodeMonkey	**Getcoding**	**Kodable**	**Lightbot 2.0**	**Program Your Robot**	**Rapid Router**	**Run Marco**
Sequence commands	√	√	√	√	√	√	√
Simple if	-	-	√	√	-	√	√
If…else	-	√	-	-	√	√	√
Nested if	-	√	-	-	-	√	√
For	√	√	√	-	√	√	√
Do while or Repeat until	-	√	-	-	-	√	√
Recursion	-	-	-	√	√	-	Future version
Functions	√	-	√	√	√	√	Future version
Object Oriented	√	-	√	-	-	√	Future version
Variables	-	-	√	-	-	√	Future version

while when creating a new object the corresponding Javascript code is presented. *Rapid Router* and *Run Marco* use *Blockly*, the standard visual programming language developed by *"Google"*. In these games the player links visual code blocks forming a set of commands, which represent a program. Additionally, in the last levels of *Rapid Router*, the player writes commands in *Python*, seeing at the same time the visual code blocks that correspond to his program. After completing some levels with this method, eventually the player ends up writing code directly to *Python*. In *CodeMonkey*, the player writes lines of code in a real open-source programming language called *CoffeeScript* that compiles to JavaScript. Alternatively, the player selects an icon from a toolbar at the bottom of the screen and this automatically writes the corresponding text command in the programming editor. Finally, *Getcoding* uses a simple visual programming language where the player selects commands from a toolbar and arranges them appropriately in the editors' programming area, forming a flow chart which corresponds to the program (Fig. 2).

4.5 Program Execution – Test and Debug

All the aforementioned games provide some facilities in order to test and debug the program that has been written from the player. With the exception of *Getcoding* and *Program Your Robot* all the games highlight the command that is being executed. In *CodeMonkey*, *Kodable*, *Lightbot 2.0* and *Rapid Router* programs can be run at different speeds while in *Run Marco* the program runs quite slowly, providing a good base to the player to track and trace the errors in the program. Corrective feedback corresponding to an error made in the program is provided in *CodeMonkey, Getcoding, Program Your Robot* and *Rapid Router*, while *Kodable* highlights the location of the error. In addition, the only game that allows the player to test and debug a solution before executing it is *Program Your Robot*. Specifically, the player can watch the program executing and in the case of a logical error explanatory messages appear for helping him in correcting it [10]. *Rapid Router* allows a step-by-step execution of commands. In all other games testing and debugging is only possible through running the program written by the learner. Furthermore, *CodeMonkey*, *Lightbot 2.0*, *Program Your Robot* and *Rapid Router* allow the player to stop the execution of the program.

4.6 Support for Online Classrooms

CodeMonkey, Kodable, and *Rapid Router* give the teachers access to a dashboard where they can create online classrooms and monitor in real time the progress of the students that have enrolled in. In addition, in *Kodable* the teacher can choose and assign specific activities of the game to a class. In *Run Marco* this feature will be available in a future version of the game in which the teachers will also be able to create their own curriculum either by selecting specific games' activities or by creating their own activities that they can assign to a class.

4.7 Creating Customized Game Levels

Kodable, Lightbot 2.0 and *Rapid Router* are the only games which support the creation of new levels. In *Lightbot 2.0* the player can create new levels and make them available to the community. In *Rapid Router* both the teacher and the student can create their own levels, while in *Kodable* if the players complete the first lesson on conditionals, they are able to access *Maze Maker* and create their new mazes. Furthermore, *CodeMonkey* also supports this feature only with user subscription, while in *Run Marco* it will be available in a future version according to its creators.

4.8 Available Platforms

All the games presented in this study are on-line games accessible through a modern web browser. We must note, however, that at the time of writing this paper, the game *Program Your Robot* is not available through the web. Some of the games are available also through specially designed mobile apps that run on Android or iOS. *Lightbot 2.0* is available only through the web, but there are other versions of the game e.g., *Lightbot Hour of Code* (www.lightbot.com), *Lightbot Jr 4+* which are available through mobile apps for Android or iOS.

5 Discussion

Table 2 summarizes the characteristics of the games in order to facilitate the readers in their comparison. The games presented in this study utilize an interesting scenario that can motivate young students in carrying out programming activities in a playful way. However, the games are not characterized by a wide variety of activities since the majority of them implement a scenario in which the player must direct a hero to a specific point or guide him on a path. Only in some activities of *CodeMonkey* the player is asked to correct the errors in a ready-made code section, while *Kodable* offers the widest variety of activities in relation to the rest, implementing three different scenarios in each of the three sections of the game. However, what seems to be missing from all the games analyzed is a more active interaction of the player with the virtual world.

Regarding the games' genre, it is clear that all the games are classified as puzzle games with the exception of *Kodable*, since it also supports other types of activities besides puzzles.

All of them provide some kind of support to the player either through tutorial levels, guiding the player step by step to solve the assigned task or displaying appropriate help messages, while some games provide video explanations. The majority of the games reward the player by displaying messages on the screen after successfully completing an activity while *CodeMonkey* and *Program Your Robot* are the only games which support a total score for the player. Also *Rapid Router* rewards the player with a score for each level individually.

Regarding the educational content, *Rapid Router* covers most of the programming concepts in relation to the rest of the games, being followed by *Kodable* and *Run Marco*, although *Run Marco* will cover all the concepts presented in Table 1 in a future version according to its' creators. *Recursion* is supported only in *Lightbot 2.0* and *Program Your Robot*, while *Lightbot 2.0* is the only game that does not include tasks with *iterative structures*, proposing instead, the use of *recursive* calls. All the games support *sequence commands execution* and *Getcoding, Rapid Router* and *Run Marco* are the only games which incorporate activities with *nested if*. *Object oriented programming* concepts are covered by *CodeMonkey, Kodable* and *Rapid Router*, while *Kodable* and *Rapid Router* are the only ones that support the concept of *variable*. It is obvious that all the games presented in this paper aim to teach basic programming concepts to novice programmers. Additionally, their activities are characterized by reasonable increasing complexity and they do not require prior knowledge from the player. Therefore, we believe that all of them could be used to teach basic programming concepts to primary school students although some of them, such as *Ligthbot 2.0*, could also be used at a higher level of education.

With the exception of *CodeMonkey* in which the player writes lines of code using the open source language *Coffescript* and *Rapid Router* where the player writes commands directly to *Python* in the last levels, in all the other games the player creates his program visually. Specifically, in *Kodable, Lightbot* and *Program Your Robot* the player "*drags and drops*" from a toolbar visual icons (commands) in an area of slots, while in *Getcoding*, *Rapid Router* and *Run Marco* the player links visual code blocks forming a set of commands. In *Getcoding* the player has the ability to see the code he wrote, translating the visual code blocks to commands of a real programming language like *Javascript*, while the same happens at the last levels of *Rapid Router* as well, where the player can see the representation of the visual code blocks that he has joined, in *Python*. *Kodable*, in the activities related to object oriented programming, allows the player to see the Javascript syntax that corresponds to an object and also to modify some properties of the avatar using Javascript syntax.

All the games provide facilities in order to test and debug a solution. With the exception of *Program Your Robot* where the player has the ability to test the code before running a program, in all the other games testing and debugging is only possible through running the program and watching the behavior of the avatar.

Online classrooms are supported in *CodeMonkey, Kodable* and *Rapid Router*. Furthermore, *Kodable, Lightbot 2.0* and *Rapid Router* allow building new levels through a game level editor. As far as some practical issues are concerned, the trend that exists today for such games is their distribution mainly via web platforms, while some of them are also available through mobile apps either for Android or iOS devices.

Finally, it should be noted that none of the games presented in this study support *collaboration* between students (players) during game play. All the games have been designed for a single player. Multiplayer or collaborative games are more motivating and engaging than single player games [1], create an environment that is safe and socially stimulating for all students entering computer science [20] and this feature should be taken into account when designing an educational game [12]. Moreover, even the games that support online classrooms and monitoring of students do not offer or offer to a small degree *learning analytics* [21]. Learning analytics could assist teachers effectively in monitoring students' progress in game play and more importantly in comprehending the programming concepts under investigation. Such analytics could report data such as, *activity metrics* which are the ways in which each player interacts with other users and with the game's avatars while playing, *the session time* which refers to the time the player needed to finish the game and also *the time that the user last accessed* the game, *various assessment methods* in order to ensure that the player has comprehended correctly the programming concepts being taught, *the number* and the *type* of the *errors* made by a student and at *what point of the game* they occurred. Other learning analytics could be *collaboration metrics* which include collaborative interactions between players, e.g. *chat content* or *number of chats* and *engagement and performance metrics* which could refer to unexpected behavior of the player in the game or to a system fault [21]. The games we compared in this study that support online classrooms and monitoring students' performance, offer learning analytics to a small degree. *Rapid Router* for example, reports the total time needed for the player to finish a level and the exact time he started and finished it, while *CodeMonkey* reports the last time that the player finished a level.

Table 2. Games characteristics.

	Features	CodeMonkey	Getcoding	Kodable	Lightbot 2.0	Program Your Robot	Rapid Router	Run Marco
		Games						
	Age	9+ (designers)	10+	5-11(designers)	9+	10+	5-16 (designers)	6-12 (designers)
Scenario	**Variety of activities**	Program the movement of a character	Program the movement of a character	Program the movement of a character; Build defense towers; Destroy asteroids	Program the movement of a character	Program the movement of a character	Program the movement of a character	Program the movement of a character
Scenario	**Selection of avatar**		√	√	√ (Hour of code)			√
Scenario	**Enemies**			√		√		
Scenario	**Activities offered**	Design an algorithm; Fix errors in a program	Design an algorithm	Design an algorithm; Assign value to a variable;	Design an algorithm	Design an algorithm	Design an algorithm	Design an algorithm
Game Mechanics	**Scaffolding/ Support**	Tutorial levels; messages before an activity	Video	Tutorial levels	Tutorial levels	Video	Messages before an activity	Tutorial levels
Game Mechanics	**Score**	√				√	√ (for each level)	
Game Mechanics	**Reward after an activity**	√	√	√			√	√
Game Mechanics	**Reward better solution**	√	√	√		√	√	√
Game Mechanics	**Achievements**	√	√			√		
	Language	Coffescript	Visual text blocks	Visual symbol icons; Javascript	Visual symbol icons	Visual symbol icons	Blockly; Python	Blockly
Program execution Test and debug	**Highlighting the command being executed**	√		√	√		√	√
Program execution Test and debug	**Run a program at different speeds**	√		√	√		√	
Program execution Test and debug	**Corrective feedback in case of an error**	√	√	Highlights the location of the error		√	√	
Program execution Test and debug	**Testing and debugging**	Through running the program	Through running the program	Through running the program	Through running the program	Before execution	Step-by-step execution	Through running the program
Program execution Test and debug	**Stop progam execution**	√			√	√	√	
	On-line classrooms	√		√			√	Future version
	Create new levels	√ (with subscription)		√	√		√	Future version
Availiable Platforms	**Web**	√	√	√	√	√	√	√
Availiable Platforms	**Android**		√		√ (in other versions)			√
Availiable Platforms	**iOS**		5.1.1 or later	6.0 or later	√			√

6 Conclusions

In this paper a comparative analysis of seven online educational games that aim to teach basic programming concepts to novice programmers was presented. All the games utilize an interesting scenario in order to motivate the players and the majority of them were classified as puzzle games. It was also found that most of the games cover basic programming concepts such as *sequence commands*, *simple* and *nested if statements*, *loops* or *functions* with the exception of *CodeMonkey*, *Kodable* and *Rapid Router* that cover more complex concepts, such as *object oriented programming*. Since the objective of this study was to present games that could be used by primary school students, the variety of programming concepts covered by them is considered satisfactory as more complex programming concepts would be difficult to approach at these ages. In addition, it was found that most of the games allow the player to create his program using visual commands and provide facilities in order to test and debug a solution.

Kodable, *Lightbot 2.0* and *Rapid Router* are the only games that allow the player to create new levels through a game level editor. This functionality is very important for a game because it can allow the teacher to create his/her own curriculum adapted to the needs of his/her class. Furthermore, our personal perception is that the existence of ready-made educational material would be very useful for teachers and would motivate them to incorporate such games in their courses. Specifically, the educational material could include exercises related to the game for each lesson, as well as some educational videos that would explain the theory behind the programming concepts taught by the game.

A significant limitation identified in the games presented in this study is the *absence of collaboration*, since all of them have been designed for a single player. Finally, *learning analytics* that could assist teachers effectively in monitoring students' progress in game play are supported on a very small degree only in two of the three games that provide the ability to create online classrooms.

Further research on this field could focus on extending the list of games that are comparatively analyzed and carrying out experimental studies for investigating their effect on students' comprehension of programming concepts. It would also be interesting to incorporate in this type of games features that are currently missing, such as collaboration during game play, enhanced interaction between the player and the virtual world, learning analytics, support for preparing customized lesson plans and activities by the teacher, and studying their effect on both students' engagement and comprehension of programming concepts and teachers' acceptance of utilizing such games in the teaching and learning of programming.

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Development of a General Purpose Interface for a Microcomputer-Based Laboratory

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Abstract. In this work, a general-purpose interface is proposed for an open, low-cost Microcomputer-Based Laboratory (MBL) system. The Arduino Uno board is programmed to act as a data acquisition device that receives and processes data from analogue or digital sensors and transmits the results to a computer via a USB connection. At the same time, on the computer, the libreMBL-GUI application, developed with the Python programming language, enables serial communication to be set up for interactive user-system communication, the start and end control of real-time graphical representation of the measurements, interactive student navigation on graphs, and data storage for later processing. The proposed system is open-source, cross-platform, and transparent to the material. Thus, it can support different Arduino types, while it can display the measurements of any compatible sensor connected to the Arduino board, provided that the appropriate sketch has been created and downloaded to the microcontroller. The system has been tested with temperature, pressure and distance sensors, covering a wide range of experiments in both Secondary and Primary Education levels. The created sketches follow a common pattern to make it easy to expand and adapt to different sensors.

Keywords: Arduino · Microcomputer-Based Laboratory · Graphical user interface

1 Introduction

The laboratory environment, in which students work together - mainly in small groups - and participate in laboratory activities, has been recognized as a unique learning environment that motivates students, strengthens active learning, while enhancing them with the experience and practice of scientific research [1]. Inquiry in general, and especially in the context of laboratory activities, has a central place to achieve scientific literacy [2], which is a central goal of Science Education [3]. Students involved in inquiry-based activities are actively involved in the process of formulating questions, predictions and assumptions, designing experiments, using tools to collect and analyze data, and drawing conclusions on scientific problems or phenomena [4, 5].

In the modern school lab environment, the development of digital technologies or Information and Communication Technologies (ICT) contribute to upgrading the teaching process and improving the quality of learning, as they provide new tools and environments for collecting, editing, visualizing data, and communicating the results.

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The technological characteristics of ICT exploit the properties of space and time, as they record, process, manage and transfer a large amount of data in an extremely short time, and present the results of the processing through dynamic, interactive and multiple representations [6].

Microcomputer-based laboratories (MBL) connect sensors, data acquisition devices, computer and management software for instantly receiving real-world data, their processing and visualization in real time. Sensors detect physical quantities variations and usually convert them into electrical signals (voltage or current), producing a measurable output, while the Data Acquisition (DAQ) device functions as an interface between the computer and the signals from the sensors. A variety of sensors can be connected to the same interface, supported by the same software and exploited in many experiments [7].

MBL systems offer a powerful learning environment for students to handle equipment, such as in traditional laboratories, to explore and quantify the physical world and make measurements under different experimental conditions and at unusual time scales. Moreover, the time spent for time consuming processes of data collection, processing and visualization is minimized [7, 8]. Students have additional time to repeat, evaluate, or improve an experiment, focus on interpreting and evaluating data, link graphic representations to physical concepts, develop skills to create and interpret graphics, and work together in teams [9].

The main disadvantage of MBL systems, which makes them less popular compared to traditional laboratories or simulations, is their increased cost [10]. Commercially available options are costly, do not work with different manufacturer's equipment and are of a closed nature, so that any modification, improvement or customization by the user, which affects the life cycle of the device, is not possible [11, 12].

The advancement in electronics and integrated circuit technology has led to the development of low-cost and open-access laboratory systems, based mainly on open hardware and software. The Arduino platform is one of the most popular open-source projects; the use of microcontroller-based technologies offers flexible ways to control experiments, data acquisition, and laboratory instrumentation on personal computers. Recently, several projects have been implemented for the development of integrated general-purpose DAQ systems based on microcontrollers, aiming to make measurements in educational laboratories simple, accurate and transparent. Plasduino [13], Edaq530 [14], openDAQ [15] or LibreLab [11] are among those DAQ systems. In addition, there is a great interest in the development of special types of systems, for enriching laboratories with low-cost special laboratory, educational and research equipment, their utilization in a specialized range of laboratory experiments [16–18], or for environmental measurements and studies [19, 20].

The existing low-cost systems for data acquisition and control experiments have the following drawbacks with regard to their use in school science laboratories as MBL systems:

- They are specified to certain experiments and therefore can not satisfactorily cover all the needs of the school laboratories, except after major interventions (in software and hardware).

- Integrated generic systems outweigh the needs of school laboratories. However, the complexity they present requires a considerable amount of time investment for science teachers to learn about their use. In addition, their proper use requires the continuous support of the development team for the procurement, maintenance and upgrading of hardware and software, which cannot be done for all available systems (and in the wide range required in case a system is adopted by a large number of school laboratories).
- In some of the special or general type systems, the online support offered is incomplete or inadequate, making them unusable outside the research team that developed them.

The above disadvantages of the existing systems have led to the development of the proposed MBL system, which has the following advantages:

- It is based on the Arduino platform, which is pre-assembled and therefore can be used without user-customized adaptations and at a very low cost. It is also supported by an extensive community of users, who communicate their knowledge over the Internet.
- The Arduino programming environment, the Python programming language, and the libraries used, are freely available and, therefore, potential users do not have to pay the cost to adapt the code to their needs.
- The code, which is freely developed and available, is simple and compact, so the potential user can use it as is or with small interventions/extensions, without the need for ongoing programmer support.
- The development of the system was made from the beginning with the aim of the school lab workshops, while trying to maintain the simplicity of the user interface, in order to be adapted to the students' knowledge-level.

2 Methodology

2.1 Aim

This work proposes the collaboration of the Arduino platform (open hardware/software) with the Python programming language for the development of the MBL System for the school lab workshops, with the following specifications:

- being of low-cost, so that it is possible to provide equipment for groups of students and not to limit its use only to demonstration experiments
- not being a "black box", but having a transparent internal function, which also increases the pedagogical value of the system
- being easy to create, modify, use and expand
- being open-source, so that the code can be freely used, modified, or extended by its users
- being cross-platform
- fully controlled by the computer for real-time data visualization and large storage space availability

- providing teachers and students with a simple, easy-to-use, general-purpose graphical interface for acquiring data from a wide range of sensors, storing and plotting them in real time
- inspiring teachers and students to participate in open-source software development, open-source technologies, and open-source communities.

2.2 Experimental Layout

The four main components of the system are:

(i) the Arduino/Genuino Uno board
(ii) analogue and digital sensors that are properly connected to the Arduino board
(iii) the programs (sketches in Arduino terminology) for each sensor or combination of sensors, running on the Arduino board microcontroller
(iv) the Graphical User Interface (GUI) for interactive user-system communication.

The Arduino/Genuino Uno board is programmed to act as a data acquisition device, which periodically receives and processes measurements from analog or digital sensors and sends the results to the computer via a serial connection for display in comprehensible form by the students.

Five (5) sketches for analogue and digital pressure, temperature and distance sensors (Table 1), which cover a wide range of experiments in both Secondary and Primary Education (e.g. temperature and heat measurement experiments, experimental approximation of gas laws, study of simple harmonic oscillation or slanting, experiments in biology, environmental measurements), were created to capture, process and send data to the computer.

Table 1. Tested sensors.

Type	Sensor
Temperature	Low voltage temperature sensor TMP36
	Analog waterproof temperature sensor LM35 series
	1-wire digital thermometer DS18B20 (waterproof)
Pressure	Digital I2C barometric pressure/temperature sensor BMP180
Distance	Ultrasonic sensor HC-SR04 for distance calculation

The criteria for selecting the sensors for testing the system are related to their general characteristics [21–25], their low cost, their availability in the local market, adequate documentation by the manufacturers and the Arduino user community, the convenience to compare analog and digital sensors that detect the same physical quantity (e.g. temperature), and the ability to experiment with digital sensors supporting I2C or 1-wire (Figs. 1 and 2).

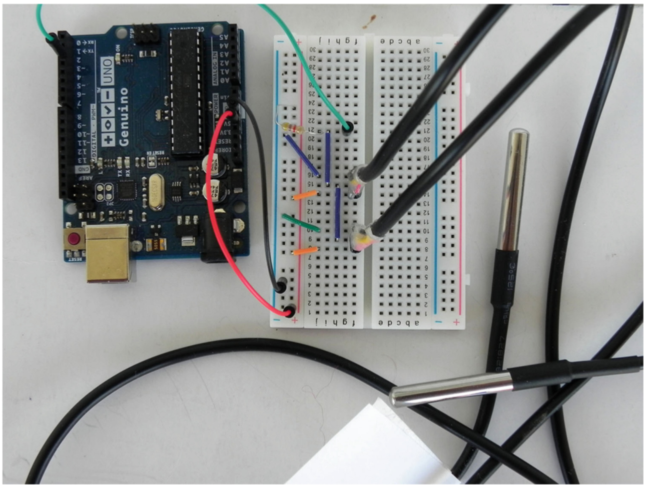

Fig. 1. Connection of two (2) 1-wire DS18B20 sensors in Genuino Uno.

To easily connect and disconnect the sensors with the Arduino board, a breadboard was used to create temporary circuits and prototypes, without the need for welding the components. Sensor pins were placed in the appropriate breadboard slot holes and then breadboard jumper wires were used to interface with the board.

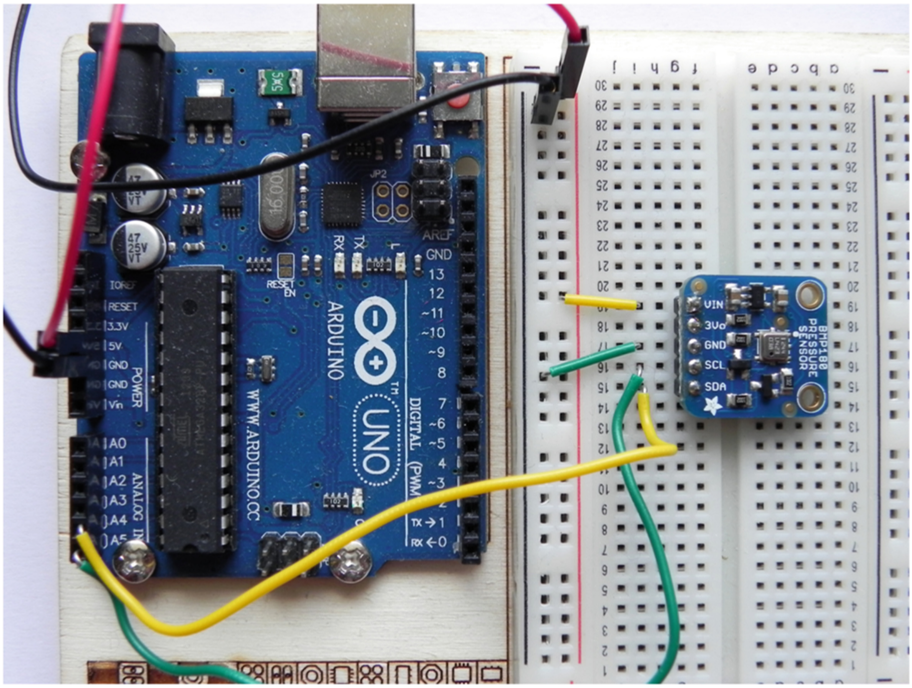

Fig. 2. Connection of the digital I2C sensor BMP180 in Arduino Uno.

The sketches were created on the cross-platform Integrated Development Environment (IDE), designed for non-experienced programmers. IDE integrates and significantly simplifies the steps of writing, editing, compiling and uploading the corresponding code to the microprocessor, along with the free material (libraries, examples, training material) available through the Internet.

On the computer side, the open-source "libreMBL-GUI" application, developed with the Python programming language, provides a simple and easy-to-use graphical user interface for real-time graphical representation of results, interactive navigation of the student on graphs and data/graphical storage for later processing.

3 Results

3.1 Programming the Arduino Board

The sketches created for the temperature sensors (TMP36, LM35, DS18B20), pressure/temperature (BMP180) and distance (HC-SR04), follow a common pattern. This ensures the easy (by a beginner programmer) modification/extension of the code for different sensors or a combination of sensors. Special emphasis was placed on the following issues:

Analog sensors typically have three (3) connection pins; one connected to the supply (5 V or 3.3 V), one connected to the ground (GND), and a third that transmits a variable voltage and connected to one of the six (6) analog inputs of the board. An Analog-to-Digital Converter (ADC) reads the voltage coming from the sensor and converts it to a 10-bit digital (1024-level) number. The *AnalogRead(sensorPin)* command of the Arduino programming language returns a value in the range [0, 1023], where *sensorPin* is the analog input to which the voltage pin (*Vout)* of the sensor is connected.

```
int sensorVal = analogRead (sensorPin);
```

Then, the output value of the ADC is converted to voltage, taking into account the reference voltage of the board.

```
float voltage = (sensorVal / 1023.0) * arefVoltage;
```

The default reference voltage is set to 5 V. The *analogReference ()* command sets the internal reference voltage (INTERNAL) to 1.1 V or external (EXTERNAL) to any other external voltage value (0–5 V) to be connected to the AREF pin, thus increasing the resolution of the system but while reducing the range of the measured voltage.

In analog sensors the resolution is determined by the ADC of the Arduino board, while in the digital ones by the built-in ADC. Moreover, for the Arduino collaboration with digital sensors, it is possible to use the appropriate libraries usually proposed by the manufacturers (e.g. Adafruit, Sparkfun), which are accompanied by illustrative examples regarding the use of the library for the communication of the digital sensor with the Arduino board.

To reduce noise and improve measurement accuracy, a simple solution is the average smoothing, i.e. to receive a large number of measurements and calculate the average. To achieve a fixed sampling rate, timer interrupts were used through the MsTimer2 library [26], which allows the periodic execution of a function per specific number of milliseconds (ms).

In order for the user to start and end the measurement process, using the “libreMBL-GUI” application, the *Serial.available ()* command was used, which takes the number of bytes available for reading from the serial port. Using the command

```
if (Serial.available()>0){
  /* start measurement */
  … }
```

the built-in commands are executed if there are data that are received or already stored in the Serial Receive Buffer.

For sketch collaboration with the “libreMBL-GUI” application running on the computer, the data sent via the serial port must be separated by comma (,) followed at the end by a line break (\r\n). They concern:

- The sampling rate that is the time (ms) which, through the MsTimer2 library, regulates the periodic execution of the measurement calculation function for each physical quantity.
- The measurement (or average of measurements) for each physical quantity.

3.2 The Graphical User Interface Environment

The “libreMBL-GUI” application for interactive user-system communication was developed with the Python programming language (version 2.7) and tested on Ubuntu Linux and Windows operating systems, without modifications. The PyQt4 library (version 12) was used to develop the graphical interface, the Matplotlib library (version 2.0.0) was used to visualize the graphs, while for the Arduino board-computer communication the PySerial module (version 3.3) was used. From Python’s standard library are also included the following modules: sys, os, threading, and time.

The application is freely available as open-source software [27], while it is transparent to the material, as it can support different Arduino types. In addition, it can display the measurements of any compatible sensor connected to the Arduino board, provided that the appropriate sketch has been created and downloaded to the microcontroller. The capabilities of the application include:

- Set up serial communication.
- Start and end sampling control.
- Flexible way to graphically display data.
- Interactive user navigation on graphs.
- Storing the data in a text file.

- Saving a snapshot of the graphs in a file with the alternative file extensions png, ps, eps, svg or pdf.

In order to achieve the correct communication between Arduino and the computer, both have the same communication rate (BaudRate), which the user (student or teacher) is called to confirm in the introductory interactive display of the graphical interface environment. The default 115200 bps communication rate is compatible with most computing systems and covers the data transmission needs for the experiments to be implemented in a school lab. The program recognizes the serial port (COMX for Windows, dev/ttyXXX for GNU/Linux), displays it on the status bar and sets up communication with Arduino.

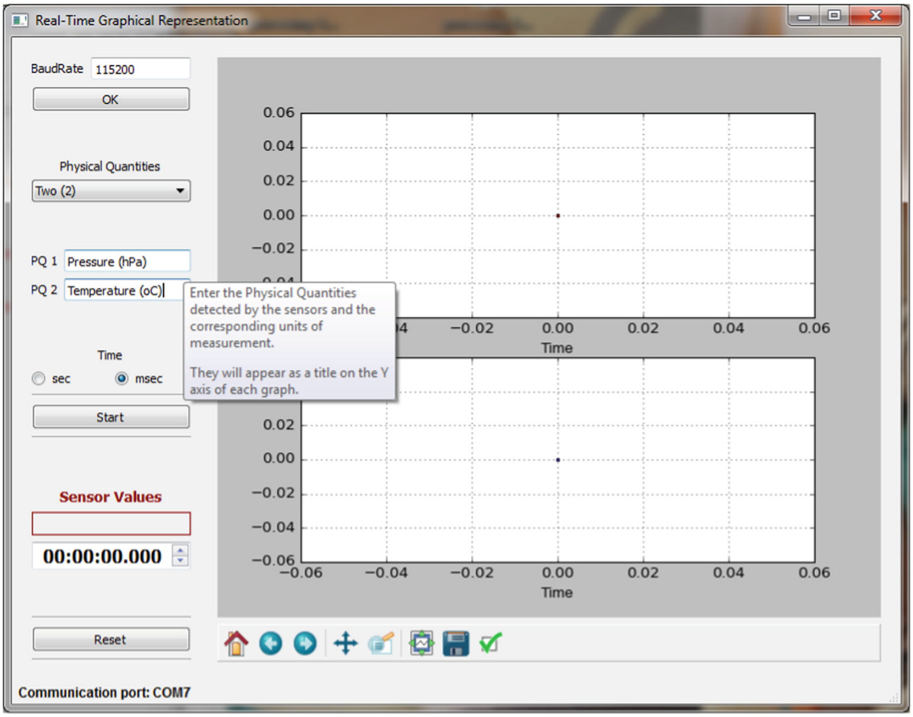

Fig. 3. The BMP180 sensor has been connected to the Arduino board and the program is prepared to capture and graphically display the pressure (hPa) and temperature (°C) measurements.

The student selects and enters (optionally) how many and what physical magnitudes the sensor (or sensors) that are connected to the Arduino board and the corresponding measuring units are detecting, in order to appear as a title on the Y-axis of each graph (Fig. 3). The program can simultaneously display graphs of up to three (3) physical quantities. By pressing the "Start" button that is immediately renamed to "Pause", the start of the process is confirmed and the sketch running on the microcontroller is updated to perform the periodic measurement of the physical quantity (or physical quantities) through the sensor (or sensors) and send the data to the serial port. The program, taking data from the serial port, displays the measurements and plots in real-time their graphical representation (Fig. 4) in terms of time (s or ms), starting at zero time (0). The graph is continuously updated, displaying the last 100 values. Also, for each value (or sensor values) it receives, it displays the actual time of the system clock. The accuracy depends on the precision of the underlying operating system, while not all systems provide 1-ms accuracy.

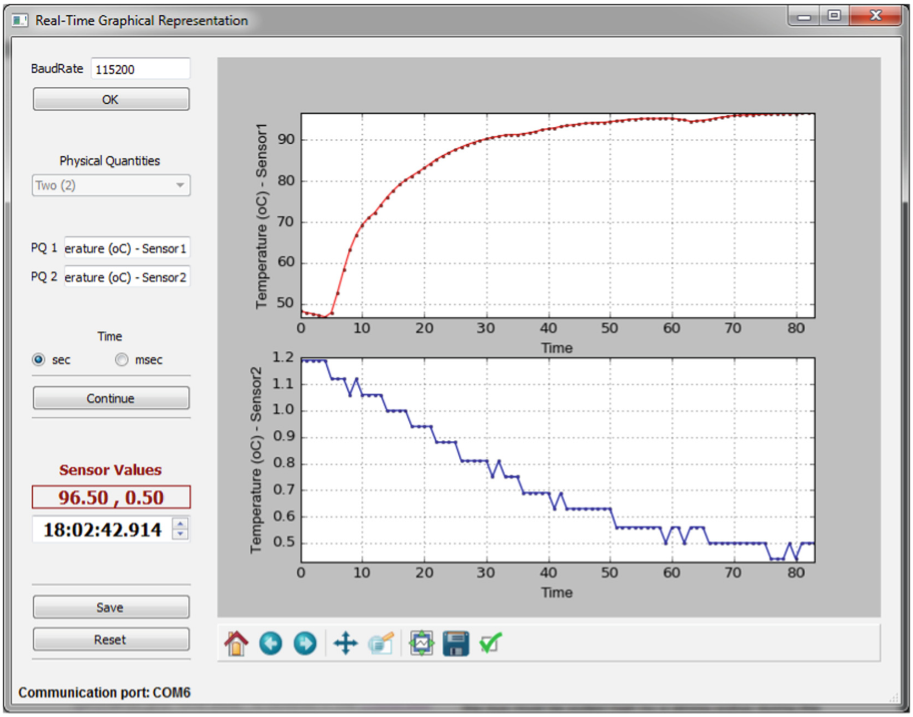

Fig. 4. Measurements from two waterproof 1-wire temperature sensors DS18B20 mounted in boiling and frozen water, respectively.

The pause mode gives the user the following capabilities:

- Select continuation of the procedure and download additional measurements (button “Continue”) or restart the procedure (button “Reset”) for new measurements with the same or different sensors.
- Save the data (button “Save”) to a text file (.txt). For each discrete measurement time-step (starting at time 0) they are saved in a new line (\n) separated by comma (,), the current time from the operating system clock, the measurements’ time (s, ms), and the measured values for each physical magnitude. In the application

folder, a folder named "data" is automatically created (if not present), and a dialog box is displayed to store the file. The file name proposed is derived from the current date and time of the system (timestamp).

- Interactive navigation in the chart area.

The Matplotlib library, used to depict graphs, provides the ability to integrate the Interactive Navigation Toolbar (Table 2) or events, to interactively navigate the user to graphically displayed data. For example, when the Pan/Zoom and Zoom-to-rectangle buttons are not selected, the user can select with left-click *(button_press_event)* points of the graph in the drawing area. Point coordinates (time, physical quantity) appear in the status bar, so that the student comparing the values draws conclusions.

Table 2. Interactive navigation toolbar buttons.

Button	Description
	The **Pan / Zoom** button has two functions: pan and zoom. By holding down the right mouse button, the user can zoom in or zoom out around an area of points of interest while holding the left mouse button can navigate panoramically.
	With the **Zoom-to-rectangle** button, the user has the ability to zoom in / zoom out an area of interest, drawing a rectangle around it by holding down the left or right mouse buttons respectively.
	The **Save** button displays a dialog box to save the current view to a file with png, ps, eps, svg or pdf extensions.

4 Conclusion

The main objectives of open systems (hardware and software) are interoperability, portability and scalability. Interoperability is ensured by adapting to a set of standards, conventions and specifications. Portability allows the system to operate on different platforms without changes, while expandability allows the user to increase system functionality. Open systems also ensure the transparency of internal operation.

Developing a system (which takes into account the specific needs of the science school laboratories) may require investment in initial development and training time but offers several advantages over the use of commercial products or even ready-made (non-commercial) similar applications. These advantages are related to low cost, simplicity, no-need for support, interoperability/portability/scalability and the ability to be operated by non-qualified personnel. A more general version of the proposed tool is under development.

The combination of the Arduino platform with the Python programming language is a low-cost but highly-effective tool for rapidly developing data acquisition applications, such as the one presented in this work; it was materialized over a relatively short period of time, because of the significant support available on the internet by the Arduino and Python user communities. In addition, using Python, in conjunction with the PyQt and Matplotlib libraries, made possible the development of a graphical interface environment that is independent of the operating system and can be used with both Windows and Linux operating systems.

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Robotics Interventions for Improving Educational Outcomes - A Meta-analysis

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Abstract. The present study reviews the literature in the field of educational robotics with the aim to identify its potential effects in students' academic performance. After a systematic search in various databases, we ended up with a total of 12 studies satisfying the eligibility criteria. The majority of studies were observational and only 4 of them were quasi-experimental. For each study we extracted data for the type of robot used, the research method used, the sample characteristics (sample size, age range of students and level of education) and the results observed in terms of scores. We synthesized results from these 12 studies using random-effects meta-analysis and found that robotic interventions have an overall positive effect in students' academic performance (0.7, 95% CI 0.283 to 1.112). We used the Cochrane Collaboration 'Risk of bias' tool to assess the quality of the 12 included studies. Most studies are at high risk of bias and this undermines the validity of results. Large, well-conducted randomized clinical trials are needed to answer the review question conclusively.

Keywords: Educational robotics · Academic performance · Lego

1 Background

Nowadays, we find technology in every aspect of our lives such as medicine, industry, home appliances, education and many more. Interest in educational robotics has increased in recent years since students are digital natives and use technology easily. Teachers are trying to include robotics activities in the teaching process and many schools and universities offer robotics lessons (in the curriculum) or robotics summer camps. It seems that robots can help the student comprehend difficult science, engineering and technology abstract concepts and transform these concepts into real-world understanding. Robots paired with specific software and curriculum offer interesting new learning opportunities and, although they are quite expensive for many school budgets, recent improvements in cost and simplicity make it possible for all students to engage in this kind of hands-on activities.

As far as it concerns the use of robotics in educational settings, there are different approaches. It can be used as a cognitive tool in a particular lesson, as a teaching technique, or as a subject area itself. Mubin et al. [1] pointed out the various roles of

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robot in education – as tutor, tool, or peer. In that way educational robots are categorized as: learning materials, learning companions and teaching assistants.

Some studies use robotics as a cognitive tool. Papert [2] argues that the computer is a tool that allows children to explore mathematics and other curricular subjects. Bellou and Mikropoulos [3] suggest educational robotics as mind tools in Physics and Computer Science education through meaningful learning activities. Educators have started to generate ideas and develop activities to incorporate robotics into the teaching of diverse subjects. STEM (Science, Technology, Engineering and Mathematics) are the subjects that use robotics activities more frequently since concepts in Physics and Technology are relevant to the benefits of educational robotics [4]. Papert [5] used Logo programming to teach geometry concepts with the movements of a turtle on the computer screen. That approach has evolved to the visual, drag-and-drop programming languages, such as scratch (MIT) and BYOB (Berkeley University).

Other studies use robotics as a tool to teach actual programming languages [6, 7], to design computer games [8] and to learn with programmable bricks [9], which led to using products like LEGO Mindstorms for Schools kits (a classic example of robots as learning materials).

Educational theorists such as Papert, believe that robotics activities have tremendous potential to improve classroom teaching [5]. Toh et al. [10] argue that students interacting with robots seem to develop several skills that can be grouped into four major categories: cognitive, conceptual, language and social (collaborative).

The use of robotics in education get students involved in interactive and learning experiences through hands-on experimentation and help children abstract science concepts into real knowledge. Through experimentation, children learn scientific and mathematic principles [11]. According to Nuget et al. [12], educational robotics supports overall STEM concepts. It also gives students the potential to develop various academic skills and to improve their achievement scores [13–15]. Another study [16] showed positive results in sequencing skills in early childhood children who interact with robots and computer programming. Sullivan [17] also claims that students who take part in robotics courses and get engaged with robotic activities such as programming and debugging improve their systems understanding and their science process skills. These skills include control of variables, hypothesis generation, hypothesis testing, calculation, construction and evaluation of solutions. Also, students in this context need to investigate questions and develop scientific argumentation skills [18, 19]. Barack and Zadok [4] suggest that children's involvement with robotics make them come up with more inventive solutions to a problem. In addition, plenty of studies indicate significant positive results in students' problem-solving approaches [6, 11, 12, 20–23]. According to Mikropoulos and Bellou [3] students use robotics as a mind tool to overcome their declarative knowledge and develop procedural knowledge aiming to the solution of a problem.

There is evidence that educational robotics indicate positive results in children's social skills. It helps them develop teamwork skills [24] and promotes cooperative learning [21, 25]. Children develop the spirit of team work and mutual collaboration [12, 26, 27].

There is no doubt that robotics is the most effective way of motivating students and supporting many subject areas of the curriculum. Robotics make learning fun and sharpen student's thinking. Students see robots as toys and this makes learning entertaining [20]. Children also increase their imagination due to the fact that this kind of activities require observation, calculation, designing, measurements and testing projects in real life context [17]. According to Johnson [24] educational robotics encourages children to use their imagination and be innovative.

Finally, students develop their language skills in order to achieve a richer interaction [28–31].

Theoretical studies report robotics' benefits in academic performance. However, despite the increasing use of robotics, there is a lack of quantitative research on how robotics can increase STEM achievement in students and only a few studies focus on the investigation of the impact. Benitti [32] points that quantitative analysis is needed to be conducted. Only a few studies provide qualitative or quantitative methods to explore the impact of robotics activities and use quantitative measures to evaluate the impact of robotics on student learning.

Hence, are robotics enhancing learning?

2 Objectives

The purpose of this review is to examine and synthesize empirical evidence on the effectiveness of educational robotics interventions on students' academic performance. The focus is on answering the following research question: Can educational robotics improve educational outcomes?

More specifically, in this review we aim to assess the effectiveness of using robotic interventions as an educational tool in improving educational outcomes in K-12 students.

3 Methods

In order to answer these questions, we conducted a quantitative synthesis through meta-analysis. We considered the following eligibility criteria:

Types of studies: studies with quantitative assessment of the benefits of robotics in learning, both randomized controlled trials (RCT) with either an experimental or a quasi-experimental (QED) research design and observational studies, published and unpublished reports of studies conducted in developed countries after 2000.

Types of participants: children in pre-school, primary and secondary school (K-12).

Types of interventions: studies that use robotics as an educational tool for a certain subject, long term and short-term studies as long as they are conducted in a school setting.

Types of outcome measures: Achievement scores, academic performance in science concepts and sequencing skills (e.g., standardized achievement tests, mean scores, grades) in major courses (mathematics, physics, language, etc.) and problem-solving abilities in form of scores. Measurement of the primary outcomes should have been conducted using standardized instruments. We excluded studies that did not provide an effect size, sufficient information or enough data to allow calculating an effect size.

Searches were based on the following search algorithm: ((teaching OR learning OR teach OR learn OR education OR educational) AND (robotic OR robotics OR robot OR robots OR Lego) AND (school OR k-12)). The search algorithm was adapted for other databases using appropriate controlled vocabulary and syntax.

We searched: IEEE XPLORE, ACM Digital Library, ScienceDirect, ERIC (Educational Resources Information Center) and Scopus.

Twelve studies passed full-text screening and were included in the review. Figure 1 demonstrates the flow chart of the study selection process.

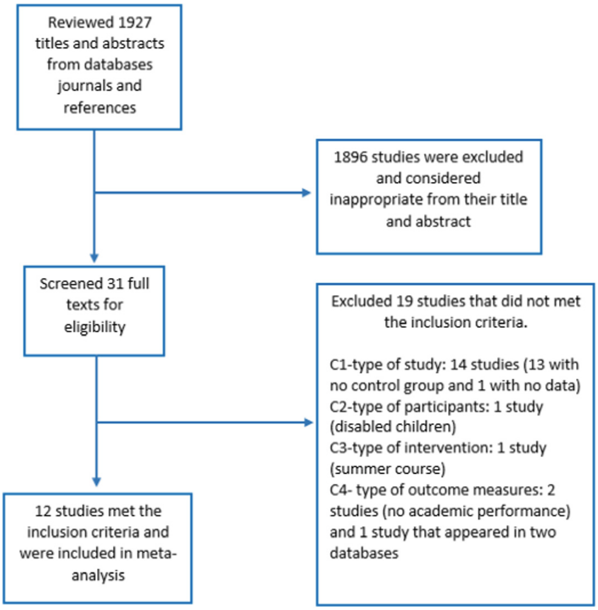

Fig. 1. Flow chart of study selection process

From the included studies we extracted data concerning: General information (title, published/unpublished, authors, year of publication, country, date of data extraction, sponsors), participants (sample size/number or participants randomized to the study, number of withdrawals, age/grade, gender and ethnicity), intervention (type(s), robot types used in the research, duration and intensity of intervention) and outcome (outcome measures, the subject that the researcher wanted to teach through robotics, primary/secondary outcomes, effect sizes).

Two review authors (LA and DM) coded each included study using the "Cochrane tool for assessing risk of bias" [33]. This includes the assessment of selection bias (random sequence allocation and allocation concealment), performance bias (blinding of participants and personnel), detection bias (blinding of outcome assessment and incomplete outcome data), reporting bias (selective outcome reporting) and other sources of bias. We reported any study characteristic that seems peculiar and may affect the magnitude of effect for the robotic interventions. The review authors judged the risk of bias as either 'high risk' of bias, 'low risk' of bias or 'unclear risk' of bias and each study was coded as "low", "high", or "unclear" risk of bias on each of the domains. In case of discrepancies the two reviewers resolved them through consensus.

3.1 Risk of Bias in Included Studies

Random sequence generation: The majority of the randomized controlled studies (n = 3, 75%) did not provide information about the method of randomization. We assessed these studies as unclear. Only one study (25%) was assessed to be at low risk of bias.

Allocation concealment: We rated all of the studies (100%) as high risk of bias due to luck of allocation concealment.

Blinding of participants & those delivering intervention: In both of the categories we rated all the studies (100%) as high risk of bias. The study design and the characteristics of these interventions cannot support blinding of participants and teachers.

Blinding of outcome assessors: Although none of the studies clearly indicates that outcome assessors were blinded we deemed that measurements were unlikely to be influenced. In this case we rated all the studies (100%) as low risk of bias.

Incomplete outcome data: The majority of the studies (n = 7, 58.3%) reported no missing data and were rated as low risk of bias. The researchers were unable to collect all the data due to dropouts from four studies (33.3%) but the number of dropouts is not mentioned. We rated these studies as unclear. One study (8.3%) provided details about incomplete outcome data but was rated as high risk due to the big percentage of dropouts.

Selective reporting: The majority of the studies (n = 11, 91.3%) report all the prespecified outcome measures and were rated low risk of this bias. We rated only one study (8.3%) as unclear since all the expected outcomes were not reported clearly at the beginning.

Other risks of bias: There were no other risks of bias in all of the studies.

4 Results

4.1 Synthesis of Results

To explore the efficacy of robotic interventions on improving educational outcomes we synthesized effect sizes from 12 studies using random-effects meta-analysis [34]. Results indicate that the overall mean effect was 0.70 and the 95% CI ranges from 0.28 to 1.11 demonstrating an overall positive and statistically significant effect of interventions on academic outcomes. We present the mean effects and confidence intervals for each study separately in the forest plot below (Fig. 2).

We noticed overall positive and statistically significant effect of robotics interventions on academic performance outcomes. Heterogeneity analysis indicated a considerable amount of heterogeneity that was statistically significant (I^2 = 90.5%, Q = 116.14, p = .00, Tau2 = .4157). Although the grand mean effect size provides evidence that the robotic interventions were, on average, effective, the large magnitude

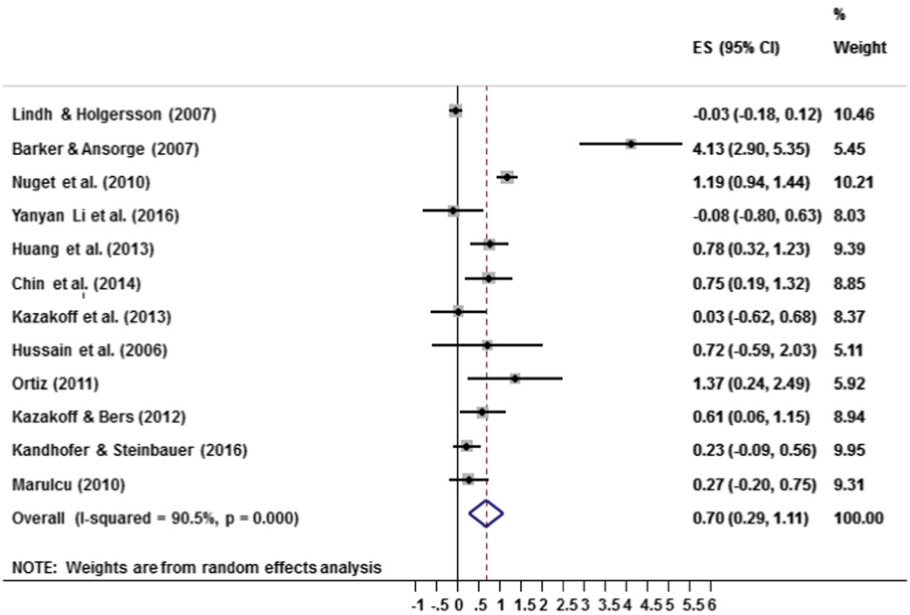

Fig. 2. Forest plot of mean effects on academic outcomes

of statistical heterogeneity suggests large variation of effects across studies. In order to predict an interval in which effect sizes from future studies will fall, we calculated the 95% prediction interval (−0.628 to 2.028). It includes zero suggesting that future trials may have a zero effect and the overall effect may move towards zero in the future. Hence, although we found a statistically significant positive effect, results are not conclusive due to the large amount of heterogeneity and more research is needed to infer about the overall effectiveness of robotics.

We conducted sensitivity analyses to investigate the influence of study characteristics on the robustness of the review results. For the 4 studies with inadequate allocation concealment and therefore at high risk of bias, the SMD was 0.76 (95% CI 0.44 to 1.08). For the 8 studies with unclear of low risk of allocation concealment the SMD was 0.32 (95% CI 0.21 to 0.43). Comparing the two size effects we note that the pooled effects do not overlap, but they only have one common point at 0.43. That indicates significant difference between studies at high versus low/unclear risk of bias judgements. Surprisingly, it is the studies at low risk of bias for allocation concealment that have a larger effect.

4.2 Subgroup Analysis

To further investigate heterogeneity, we split studies into subgroups to make comparisons between them.

Duration of Intervention. We explored the influence of the total duration of the interventions (less than a month, 1–6 months, 6 or more months) on the improvement of academic performance for the intervention groups compared to the control groups. A large effect size was observed for less than one-month interventions (SMD 0.59, 95% CI −0.10 to 1.28). A large effect size was observed also for 1–6 months interventions (SMD 1.26, 95% CI 0.14 to 2.38) and finally the effect size of more than 6 months interventions was SMD 0.27, 95% CI 0.00 to −0.53.

From the Fig. 3 a large overlapping is obvious and the heterogeneity of the sub-groups ranges at high percentages.

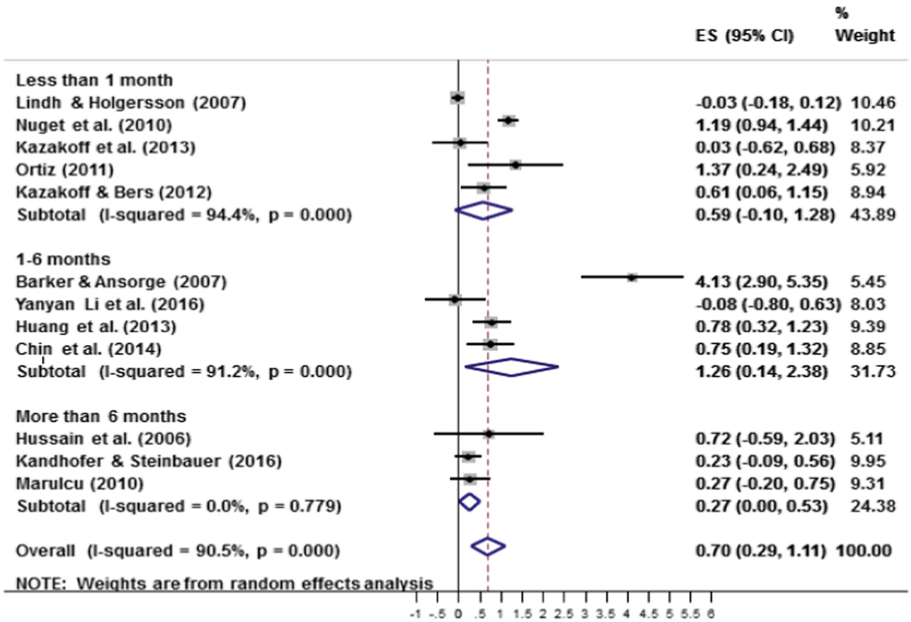

Fig. 3. Subgroup analysis - duration of the intervention

Grade of Participants. We explored the influence of the grade of participants (preK-K, elementary school, middle school, across grades students) on outcomes referring to academic performance for intervention groups versus control groups. The effect size of across grades students was 0.61, 95% CI −0.417 to 1.63, of elementary school students 1.05, 95% CI 0.30 to 1.81, of pre K-K students 0.35 95% CI −0.22 to 0.91 and of middle school students 0.23 95% CI −0.09 to 0.56. We noticed no significant difference at the subgroup analysis' results and the heterogeneity remained high, with only exception the sub-group pre K-K (Fig. 4).

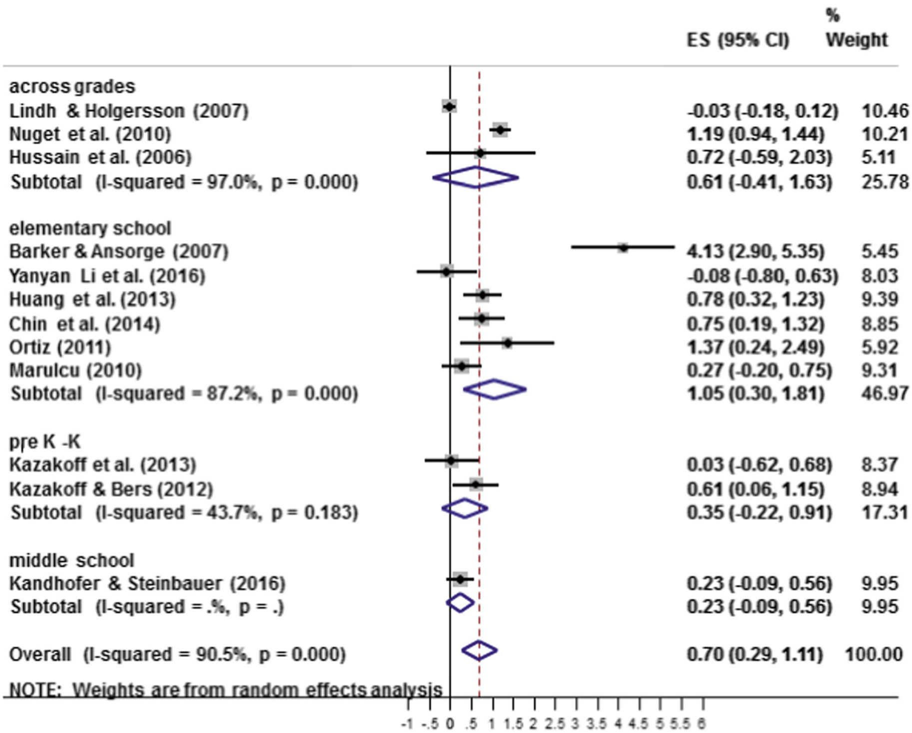

Fig. 4. Subgroup analysis – grade of participants

4.3 Small-Study Effects

We explored for small-study effects by drawing a funnel plot. Small-study effect occurs when smaller studies show systematically larger effects and is typically used as a proxy for publication bias [36].

The funnel plot, as shown in Fig. 5, is asymmetric and a few smaller studies tended to exaggerate the effectiveness of intervention, indicating the possibility of publication bias. The contour-enhanced funnel plot helped us distinguish between publication bias and other causes of the asymmetry such as heterogeneity [37]. It showed that studies were distributed not in both statistical significance and in non-statistical significance areas (grey and white).

We also run an Egger's meta-regression model [38]. The CI of bias includes the zero value and $p = 0.12$ so we cannot conclude that a significant difference exists.

We finally applied the trim-and-fill method [35]. The addition of the 6 estimated unpublished studies moved the effect size to 0.104 with 95% CI −0.332 to 0.540 ($p = 0.640$).

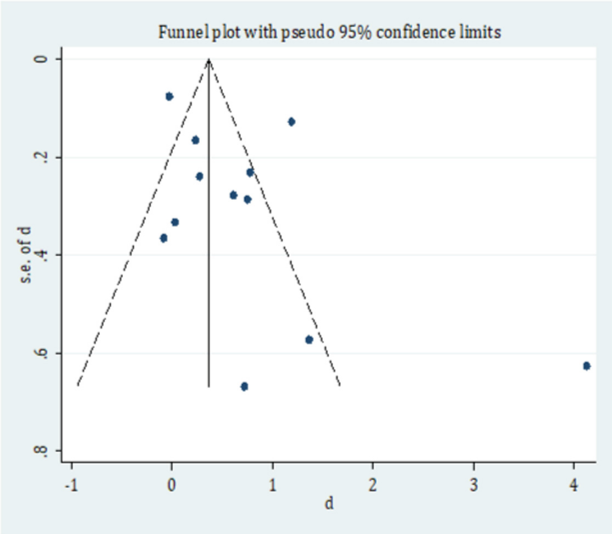

Fig. 5. Funnel plot of comparison robotics vs. control group outcome

5 Discussion

5.1 Summary of Main Results

The present review includes a total of 12 studies, 8 observational and 4 quasi-experimental, that met the inclusion criteria and examine the effects of educational robotic intervention on academic performance and problem solving ctiteria. All of the included studies provided the necessary data for a quantitative synthesis in a meta-analysis. Results of the meta-analysis indicate small positive effects. It seems that educational robotics may benefit students' academic performance but the heterogeneity of the outcomes is high and compromised the validity of results. That can be explained from the large differences in the studies characteristics and the diverse nature of the studies, both in terms of design and methods employed. The review of the studies indicates a lot of difference among studies as far as intervention's duration, type of robotics used, age- grade applied etc. The subgroup analysis conducted to clarify these differences also shown high heterogeneity in the majority of the sub-groups. It is really common in social studies that there is not much explanation in methodological details and some fields were unclear, for example a lot of studies mentioned the intervention's duration but not the frequency of the total hours or mention about students that are not included in the results but do not explain reasons of drop out. Given the quality and high risk of bias across studies in several areas, caution must be used in the interpretation of the study results.

The sensitivity analysis indicated differences between quasi- experimental studies and observational studies. It is important to mention the low number or quasi-experimental studies and the total luck or control randomized trials.

The results of the sub-group analysis also show that long term interventions have greater impact and present better outcomes, with largest effect size at the group of 1–6 months interventions. But not very long term while at the group of 6 months and more the effect size decreases. This can be explained because academic outcomes are often more difficult to change immediately, and given that the studies in this review measured grades, it may take a longer periods to see change in grades. On the other hand students in the long term interventions may lose their interest.

The sub-group analysis for the students' grade gave larger effect size at the group of elementary school students. As it was expected from the literature the majority of studies are carried out at elementary schools. The other groups also have positive effects which indicate that robotic interventions effect academic performance in all grades (K-12).

5.2 Quality of the Evidence

The risk of bias summary gives information about the quality of the evidence. Some important risk of bias present in the majority of the studies, related to allocation concealment and blinding. That was expected due to the nature of these kind of studies. Most of them do not use randomization and blinding is very difficult as it is obvious to the stuff and students that they use robotics. These two fields (allocation concealment and blinding) are the prime reasons that threatens the internal validity of the included studies and we are concerned that this body of evidence is biased in favor of the robotics due to experimenter expectancy effects. That leads to caution regarding the meta-analysis results' use and interpretation.

In all of the studies selective reporting was rated as low risk of bias. Also some of the included studies were sponsored by organizations or authorities that are not relevant in robotics industry and we are not concerned that this caused bias in favor of robotics.

Finally the funnel plot was also asymmetrical which indicates potential for publication bias.

5.3 Limitations and Potential Biases in the Review Process

During the searching for the included studies we faced difficulties, as expected from the literature, such as the low number of relevant studies and the luck of studies with enough empirical data and comparison between treatment and control groups. We made every attempt to search for published studies, however, the majority of the studies were published journal articles and only one of them was an unpublished dissertation. Another limitation was the geographical restriction and some not accessible databases that may gave us further studies and more information. Finally, there is some indication of publication bias present, which could be upwardly biasing the mean effect for the outcomes examined in this review.

5.4 Future Suggestions

Although results suggest that robotic interventions are likely to improve educational outcomes, differences across studies induce large heterogeneity that compromises the validity of results. Further research is needed to get conclusive results. More specifically similarly conducted randomized control trials in elementary school students may help us draw valid conclusions.

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Students' Engagement and Peer Interaction in On-Line Academic Writing Through a Course Blog

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Abstract. Academic writing is considered one of the most critical competencies that university students need to develop and constitutes an integral part of contemporary educational programs in higher education. This paper presents an analysis of students' engagement in online academic writing associated with inquiry and peer interaction practices through a course blog. The intervention was designed in the context of a blended postgraduate course under the assumption that on-line writing in the course blog could promote students' academic writing skills. The key aspects of student generated content, peer interaction and reflection in the course blog were directed by the principles of e-learning 2.0. Descriptive and Social Network Analysis revealed important information regarding individual students' contribution, peer interaction and the network structure of a learning community that was emerging in the course blog.

Keywords: On-line academic writing · Educational blogging · E-learning 2.0 · Learning presence · Social Network Analysis

1 Introduction

E-learning is nowadays becoming more widespread in higher education and new pedagogical philosophies, design models and forms of learning are dynamically emerging. The Web 2.0 technologies, like on-line platforms, open educational resources, blogs, wikis, social networking media, multiuser virtual environments etc., shape new directions and challenge educational organizations to consider new ways of delivering their on-line programs. In this perspective, Web 2.0 technologies have fundamentally changed the way we think about e-learning environments, pedagogical strategies, as well as students' learning activities and outcomes. Therefore, a radical shift in e-learning pedagogy is quite apparent from the traditional-individual perception of learning to new dynamic and emerging approaches that put emphasis on authentic, participatory, interactive, self-directed, and collaborative processes within communities of learners who share common interests and goals [3, 6, 20, 30].

Changing our notion of teaching and learning, from time and space bound classroom places to flexible, participatory, collaborative, distributed and networked virtual environments, is not a new idea [1, 26]. In this perspective, Web 2.0 tools have moved

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this debate forward by offering a wide range of affordances to create enhanced and dynamic learning spaces that promote on-line writing, exchanging ideas, sharing information and resources, and promoting networking among learners [10, 19, 28]. Within appropriate educational contexts, Web 2.0 applications can be transformed into participatory (task-oriented), personal and social learning spaces, independently of physical, geographical or institutional boundaries [9, 14, 20].

Blogs in particular have received a growing educational and research interest and a wide range of studies are reported in higher education [12, 13, 17, 19, 30]. Existing research findings have shown that educational blogging provides enhanced opportunities to the students to achieve deeper understanding and knowledge construction through sharing resources, expressing and exchanging ideas, critical and reflective thinking, group work and collaboration in both, blended and on-line forms of learning [2, 15, 21, 23, 27–29].

Literature review on current empirical investigations suggested that a wide range of published studies were directed towards students' perceptions of blogging and their experiences during learning activities within educational blogs [4, 19, 27]. Therefore, there is need for further empirical research regarding students' patterns of engagement and learning presence in educational blogging activities. In particular, finding new ways of integrating educational blogs into existing institutional and learning contexts in higher education is an open research topic.

Despite that academic writing skills are considered as key competencies that university students need to acquire in their studies [8], literature review regarding online environments for academic writing showed that this topic is actually at a starting level. In the last years, blogs appeared to be a new means to promote students' on-line academic writing and argumentation [11, 16, 18, 33].

The present study has two main objectives: (a) to explore the patterns of students' academic writing, debate and reflection in the context of a masters' degree course, (b) to analyse students' performance by identifying critical indicators that represent individual contribution, peer interaction, the influence each student had to the others, and the overall structure of an emerging community academic writing in the course blog. In accordance to the research objectives, the following research questions were addressed:

- To what extent the course blog afforded an effective learning environment that promoted students' academic writing as members of a learning community?
- Can we estimate students' individual contribution, and depict their social interactions and roles in the course blog of academic writing?

The paper is structured as following. The theoretical foundations of on-line academic writing through blogging which addressed the design framework of the present intervention are outlined. The methodological issues of the research as well as the preliminary findings of both descriptive and Social Network Analysis (SNA) are presented to depict students' overall performance and structure of the learning community created in the course blog. The results provided supportive evidence that on-line academic writing was an effective learning activity and promoted students' mutual interaction and learning presence.

2 Theoretical Framework and Literature Review

2.1 E-Learning 2.0 and Student Generated Content

The notion of e-learning 2.0 was introduced by Downes [5] to describe new pedagogical approaches, educational initiatives and learning activities that harness the core features of Web 2.0 applications. By adopting the fundamental ideas of connectivism, he described e-learning 2.0 as a range of approaches that provide to the learners enhanced opportunities to create and cultivate their own learning as active members of learning networks through reflexive dialogue, creativity, collaboration and self-direction. In addition, Brown & Adler described learning 2.0 as a new form of technology enhanced learning in specific Web 2.0 spaces that afford the emergence of open and participatory learning ecosystems supporting active, creative and sustainable communities of learners [1].

In this context, the debate regarding e-learning 2.0 means to go beyond oversimplified notions that conceive the educational Web 2.0 as a space for educators, i.e. for providing educational content to the students. Educators need to conceptualize Web 2.0 as a space for learners, i.e. for active, self-directed and collaborative learning. Under this lens, we have identified six interrelated dimensions of the educational Web 2.0 that integrate its technological, social and learning features in a complete and meaningful framework to be adopted by both, educators and learning designers [14]: participation, openness, interactivity, collaboration, sociability, and learning platform.

Learning within a social context means on-line interaction between learner-tutor, learner-learner and learner-members of the wider learning community. Therefore, e-learning 2.0 is a social process determined by the following key features [9, 14]:

(a) Learning beyond the classroom boundaries: e-learning 2.0 could take place always, everywhere and in many different forms and contexts. Towards building active learning communities among students, we need to adopt a blended and open learning philosophy and to cultivate attitudes of networked and ubiquitous learning among learners.
(b) Combining community and content: New forms of pedagogy, known as Pedagogy 2.0, are necessary to facilitate peer feedback, reflection, collaboration, emergent and self-directed learning [19]. Students are active learners by interacting and collaborating with peers, expressing their knowledge, creating on-line content, and participating in learning networks though peer interaction, content and knowledge sharing and distributed responsibilities.
(c) Combining e-learning and open learning: e-learning 2.0 is an evolving and long-term process, which includes open and dynamically emergent learning determined by authentic learning activities. Actually, it is addressed by an open philosophy, with open learning objectives, open procedures and an open, learner-created curriculum. In this perspective, due to their features, blogs can operate as dynamic on-line writing and collaboration spaces that support long-term academic writing activities in blended and fully online courses. A course blog, for example, offers to the students a common-integrated space operating as a content composition system, an online discussion tool and a literature repository (content source).

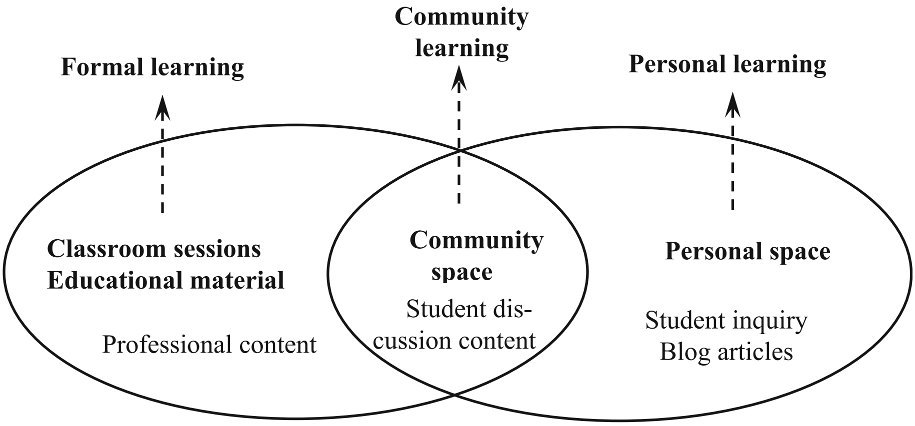

Fig. 1. Content 2.0 and on-line academic writing in blogs.

Student generated content is a new notion and a critical factor in Web 2.0 spaces [6]. It is a new type of content that students can authentically create in on-line communities, based on their knowledge, creativity, reflection and collaboration. The notion of Content 2.0 has been introduced to indicate the difference, in nature, between student-generated content in on-line collaborative environments and the officially provided content in conventional e-learning programs [9]. The actual meaning is that Content 2.0 incorporates the content evolution, the process of learning and the emerging community features.

In on-line academic writing, student performance content determines the transition from tutor-led to open learning approaches, where content is constructed by the learners themselves in a dynamic and emerging manner [6]. Student performance content elaborates knowledge construction through personal inquiry, article writing, ideas evolution, peer feedback and co-creation. This is a long-term, evolving process that combines multiple forms of learning actions, i.e. formal, personal and social. Ultimately, this process is expected to help on-line learners to transform their performance content into professional content, which they collaboratively construct as active members of a learning community (Fig. 1).

2.2 On-Line Academic Writing

Academic writing skills are traditionally considered as the key competencies that undergraduate and master students need to develop. Current trends in higher education promote the notion that university students should be properly educated to connect scientific knowledge (classroom instruction, personal readings and searching online resources) and writing skills. In this perspective, academic writing was suggested as an integral part of university students' learning, in a sense that the development of their writing abilities is practically seen as a strong indicator of knowledge construction [8].

Goodfellow advocated also that students' induction into academic culture and scientific discourse is the principal way to demonstrate the knowledge and skills they have acquired in their studies [8]. Students must have enhanced opportunities, as well as the appropriate guidance, to carry out systematic review and scientific inquiry, detailed and analytical reading of literature papers, critical thinking, argumentation and documentation, expressing and discussing their ideas in order to revise misconceptions, to internalize new concepts and to apply them in problem-solving cases [22].

Wingate, Andon and Cogo suggested that academic writing is both a process and a textual product, i.e. students' written artefacts and essays [33]. In this perspective, students' development of academic writing skills is expected to be the outcome of critical reading, dynamic scientific discourse, reflection and feedback among peers. The students involved in online academic writing are expected to draw new forms of scientific discourse by critically reflecting on their own writings and interacting with their classmates [16]. Likewise, it was reported that the integration of in-class and online writing tasks with assessment feedback was effective to support the development of students' academic writing abilities [31].

Educational blogs integrate dynamic features and offer an ideal community space for student generated content, through participatory, reflective and constructive ways. Student contributions are evolving artefacts constituted by an initial (starting) article or post and the related peer or tutor's comments. This is an integration of content and peer interaction, both appeared in the same space (the blog), which provides an overview of the topics under study and the ideas therein, students' individual contributions and reflection, peer feedback, the overall meaning and the knowledge constructed within the blog community [10].

Existing research findings, on students' engagement and interaction practices associated with online academic writing through blogging is limited. There are few published studies showing that academic writing through blogs promotes the creation of reflective and collaborative skills while the students can improve critical thinking and writing skills. For example, Kung [18] explored students' perceptions, motivation and confidence, as well as their perceived strengths and weaknesses of on-line academic writing, through blog-assisted language learning. Likewise, Novakovich [21] conducted a comparative study on students' academic writing and peer feedback by using traditional in-class methods and blog-mediated writing practices. The findings suggested improved quality in students' writing in the blog and increased peer feedback reflection in the form of critical and directive comments, which promoted students' self-assessment and metacognitive self-awareness. Kathpalia and See [16] showed that class blogs were efficient to enhance students' scientific argumentation with valid claims, evidence and rebuttals in a critical writing course. In addition, they advocated that specific pedagogical strategies, like argumentation prompts and peer-evaluation schemes, are necessary to enhance student argumentation through blogs. By extending previous research findings, we have found that students' learning in educational blogging was achieved as the outcome of reflection and collaboration among active students, members of an on-line community of inquiry [12].

3 Research Method

3.1 Context and Participants

The present intervention and the consequent study were conducted in the context of a masters' degree course regarding e-learning and its applications in educational practice. The main objectives of this course were to enhance students' theoretical knowledge in e-learning and learning design skills, as well as their ability in conducting scientific research and communicating their achievements to an audience consisted of their peers and the instructor.

The course was offered in the spring semester of 2017. A total of 47 students attending this course were enrolled in two separate classes; the first class included 21 students and the second 26. The participants had a bachelor degree in various educational disciplines while the majority of them (40 students) were in-service teachers in primary or secondary schools.

3.2 Course Design and Workflow

The primary objectives of this blog-based intervention was to engage all students in a learning process that can (a) combine academic writing skills with individual students' knowledge and creative thinking, (b) stimulate peer interactions and collective knowledge through argumentation, peer dialogue, self and shared reflection, (c) promote students' collaboration, creativity and community identity, and (d) make transparent the learning trajectories of each individual student.

The course was designed in a blended format including five face-to-face sessions properly interwoven with students' on-line work in the course blog, both individual and collaborative. Classroom sessions, in the two classes, were separate in space and time. The course was thematically structured into two parts. In the first part, between starting and sixth week, the students were asked to do literature search and scientific inquiry regarding various e-learning topics of their choice. Between 7th and 14th course weeks each student was advocated to write two academic articles (1500–2000 words) in the form of blog publications in a WordPress platform customised by hosted at the University of Peloponnese. These articles should be related to the main course topics and the literature review that the students carried out individually.

The instructor was acting as e-moderator [24] by shaping an emergent, reflective and collaborative way of students' academic writing and performance with the aim to promote dialogue, peer interaction, self-directed scientific reasoning and collaborative inquiry as members of an on-line community in the course blog. The students were advised to use proper ways of academic writing in order to communicate their outcomes and share their knowledge with peers. Guidelines were also given to the students with regards to searching and referencing on scientific literature, doing critical evaluation of primary research articles and writing-synthesizing literature reviews. In addition, examples of good strategies of academic writing and suggestions to avoid plagiarism were given.

The students were also asked not only to restrict their activity in publishing their articles in the course blog but to get actively engaged into the blog discourse on regular and systematic basis. They were encouraged to reflect upon peer contributions through critical comments alternative views, comprehensive argumentation, expansion of ideas or themes, in order to collaboratively create a common space of valuable academic content.

3.3 Analysis Framework

The research data were collected by monitoring and recording students' publications in the blog during the second part of the course, when the on-line academic writing project was implemented (eight weeks). Students' contributions were divided into (a) academic articles and (b) comment posts, which typically included questions, replies, new ideas and arguments, proposals for content resources, and criticism about a particular article or previous peer comments. Every student publication was considered as the unit of analysis [10].

Systematic content analysis procedures, based on well-documented models of learners' discourse in on-line learning environments, were used to reveal students' performance in on-line writing, patterns of mutual interaction, ideas interchange and the social relations that determine knowledge construction within the blog community: (a) Social Network Analysis (SNA) algorithms to reveal the information flow in the course blog, students' connections and groups developed therein, as well as the power and the influence each student had within the community of on-line writing [10, 13], (b) Community of Inquiry [7] and (c) the Learning Presence [25] frameworks to connect students' discourse and individual learning evolution.

In this paper we present the results of the descriptive statistics combined with SNA formulas to map an overall view of students' on-line presence and peer interaction within the course blog. Cyram NetMiner 4.0 software was used to implement SNA. Using SNA, a social structure, the blog community in our case, can be represented as a network; every student is a node and the interactions among members (communication, information exchange, knowledge sharing etc.) is depicted as a series of links connecting the various nodes. In addition, SNA provides a set of algorithms that quantify social and cognitive interaction among members, the amount of communication (and the information exchanged), the different student roles, member groups, power or influence of individuals etc., in terms of network structure parameters. All these parameters encode certain networking forces shared among students, which are necessary to keep learning sustainable along the timeline of the academic writing project within the course blog.

4 Results

4.1 Students' Engagement in On-Line Writing

Table 1 shows the results of the descriptive analysis of students' activity in the blog during the investigation period, i.e. the comments each student published in peer articles and the comments received by the other students in his/her articles. They depict an overall picture of the academic writing part of the two courses and the contributions of each individual student. Fictitious names S1i, S2i were used to represent the students in the two classes; T was the instructors' code name. A total of 96 original articles were published on the blog which received 1399 comments that represent detailed discussions among students in both classes that were evolving during the on-line academic writing project.

Table 1. Member activities within blog community.

Student (class 1)	Comments published	Comments received	Student (class 2)	Comments published	Comments received
S1.1	31	35	S2.1	8	27
S1.2	68	50	S2.2	9	12
S1.3	13	25	S2.3	16	15
S1.4	14	32	S2.4	13	17
S1.5	61	46	S2.5	5	18
S1.6	35	34	S2.6	10	25
S1.7	53	52	S2.7	11	22
S1.8	17	38	S2.8	14	21
S1.9	32	43	S2.9	10	19
S1.10	129	41	S2.10	8	25
S1.11	84	44	S2.11	2	11
S1.12	10	30	S2.12	72	44
S1.13	15	21	S2.13	3	20
S1.14	175	61	S2.14	3	16
S1.15	52	46	S2.15	20	19
S1.16	25	30	S2.16	6	17
S1.17	63	20	S2.17	0	23
S1.18	21	40	S2.18	20	21
S1.19	34	37	S2.19	77	48
S1.20	45	36	S2.20	21	20
S1.21	21	40	S2.21	15	31
			S2.22	25	31
			S2.23	9	26
			S2.24	0	18
			S2.25	9	20
			S2.26	11	26
T	4	6	T	4	6
Total	1399	1399	Total	1399	1399

Students on-line articles were related to various theoretical and research topics, i.e. e-learning, ICT-based educational practices, learning design, Web 2.0 in education, collaborative learning, flipped classroom, learning communities, open educational resources, digital storytelling, MOOCs, etc. Figure 2 shows a screenshot presenting a typical student article related to the topic of "Learning Analytics" and the discussion among students through 24 peer feedback and reflection postings. Table 2 presents indicative examples of student's posts showing their ideas and argumentation that promoted reflexive dialogue and enriched the initial blog article.

Fig. 2. Blog platform showing a typical article written by student S1.2.

Table 2. Examples of student reflection posts.

Post number	Student	Blog posts
1	S1.14	… This is actually a very interesting article… Regarding to your question, I would like to say that, despite the limitations, learning analytics can effectively support research; this indicates the significance and future development of learning analytics. In particular, I would like to focus on the ability to visualize educational data in a very powerful way
3	S1.16	Dear S1.2 we have been dealing with the same topic… But your analysis was based on a completely different view and this is very helpful!

(*continued*)

Table 2. (*continued*)

Post number	Student	Blog posts
7	S1.6	Dear S1.2, your article is very interesting and deal with a up to date topic!!! It is actually a comprehensive presentation of Learning Analytics… I think we also have a similar experience in this Master's course. I will agree with S1.14 about the visualization of educational data and results; it is very impressive and useful for any educational process
8	S1.2	Dear S1.2, in the time I was writing this message there were 87 published articles and 861 comments on our blog. These numbers are very impressive; actually we could expect huge numbers in large communities. Just consider how many ideas, suggestions, questions or views we all have presented in the course blog. And there is one more month to complete this activity. Therefore, there will be a great amount of big data. How could be all this data analysed if not by using Learning Analytics methods?…

The majority of the students appeared to be effective and they contributed to both, the individual and the interactive dimensions of the on-line writing activities. They all published two academic articles and discussed on critical theoretical, pedagogical and learning design issues that emerged in the on-line discussions around blog articles. In most cases, they sent more posts than they received. Students in Class1 were more active members of the blogging community comparing to their fellows in Class2, in terms of the number of blog posts they uploaded.

Students S1.14, S2.19, S1.2, S1.10, S1.11, S2.12, S1.17, and S1.5 were the most effective learners by providing feedback, asking questions, exchanging ideas and replies, presenting new arguments and criticism, sharing and suggesting new resources, drawing conclusions and, eventually, co-constructing new content knowledge. On the contrary, there were 5 students in Class2 which had a peripheral role in the community, since they had extremely marginal presence with 2–3 sporadic posts (the students S2.11, S2.13, S2.14) or no interaction at all with other members in the blog (S2.17, S2.24).

4.2 Social Network Analysis

Individual contribution, member relationships, group dynamics and community operation were analysed in terms of network structure parameters, namely cohesion, power centrality and betweeness centrality. Cohesion analysis can reveal the architecture of the blog community in terms of subgroups (cliques) of members who tended to be connected internally more than externally, i.e. with other members outside of these subgroups. In other words, student links within a clique are stronger, on average, than with other students [10].

Table 3 shows the results of the cohesion analysis. A total of 295 student subgroups (cliques) appeared within the blog community. It is important to be noticed that the majority of the student cliques (252) included a significant number of members, ranging from 7 to 12. This indicates that a range of cohesive subgroups were dynamically emerging during the academic writing project. In other words, the students had enhanced opportunities to develop strong interrelations and, therefore, to share and construct knowledge as members of a community of inquiry.

Table 3. Cohesion analysis and student cliques.

Members within a clique	Number of cliques
12	17
11	25
10	30
9	20
8	69
7	91
6	38
5	5
Total	295

Individual contribution, member relationships, group dynamics and community operation were analysed in terms of network structure parameters, namely *cohesion*, *power centrality* and *betweeness centrality*. Cohesion analysis can reveal the architecture of the blog community in terms of subgroups (cliques) of members who tended to be connected internally more than externally, i.e. with other members outside of these subgroups. In other words, student links within a clique are stronger, on average, than with other students [10].

Power (centrality) analysis is an effective SNA method to measure network activity, to reveal the operation of the blogging community and to assess the impact each member had with respect to spreading information and influencing others in this network [10, 13]. In-degree centrality represents the number of interactions (blog posts) a student received from other members in the community. Accordingly, out-degree centrality is the number of connections a student had to the other classmates. Betweeness centrality represents the capacity of a member to act as a connector between other students, i.e., it is an indicator of individual position within the community.

Table 4 shows the results of the network activity measures that present the power distribution among participants in the community. The majority of the students were active community members, since they interacted, at least, with 30% of their peers. Students S1.14, S1.10, S1.17 and S2.19 were the most influential members, since they were connected with more than 80% of the participants. On the other hand, students S1.14, S1.2, S2.19 and S2.12 were the most popular and successful members in the community by receiving a great number of posts from their peers ($\sim$50%). It is quite apparent that some students, like S2.24, S2.17, S2.12, S2.11, S2.16 and S2.1, had a marginal contribution as community moderators.

Table 4. Power analysis of students' activity in the blog.

Student	In-degree centrality (%)	Out-degree centrality (%)	Betweeness centrality
S1.1	0.362	0.383	0.006
S1.2	0.511	0.617	0.026
S1.3	0.340	0.191	0.002
S1.4	0.319	0.234	0.002
S1.5	0.362	0.574	0.012
S1.6	0.468	0.532	0.021
S1.7	0.468	0.553	0.018
S1.8	0.147	0.234	0.006
S1.9	0.319	0.362	0.005
S1.10	0.447	0.936	0.043
S1.11	0.168	0.894	0.044
S1.12	0.298	0.191	0.005
S1.13	0.277	0.234	0.002
S1.14	0.660	1.000	0.109
S1.15	0.426	0.617	0.020
S1.16	0.383	0.340	0.011
S1.17	0.426	0.809	0.045
S1.18	0.468	0.340	0.009
S1.19	0.298	0.426	0.007
S1.20	0.362	0.468	0.006
S1.21	0.426	0.340	0.007
S2.1	0.277	0.128	0.010
S2.2	0.149	0.170	0.001
S2.3	0.298	0.319	0.009
S2.4	0.255	0.277	0.006
S2.5	0.255	0.085	0.003
S2.6	0.277	0.149	0.003
S2.7	0.277	0.191	0.005
S2.8	0.255	0.213	0.005
S2.9	0.191	0.149	0.002
S2.10	0.298	0.128	0.011
S2.11	0.170	0.021	0.001
S2.12	0.489	0.766	0.067
S2.13	0.255	0.043	0.001
S2.14	0.277	0.085	0.003
S2.15	0.191	0.340	0.007
S2.16	0.170	0.085	0.000
S2.17	0.255	0.000	0.000
S2.18	0.340	0.319	0.009
S2.19	0.596	0.809	0.065

(*continued*)

Table 4. (*continued*)

Student	In-degree centrality (%)	Out-degree centrality (%)	Betweeness centrality
S2.20	0.298	0.340	0.009
S2.21	0.362	0.234	0.015
S2.22	0.383	0.383	0.039
S2.23	0.298	0.149	0.009
S2.24	0.213	0.000	0.000
S2.25	0.234	0.128	0.002
S2.26	0.319	0.191	0.003
T	0.149	0.085	0.002
Mean	0.335	0.335	0.014

Figure 3 presents the degree centrality map which presents the overall blog activity. Student S1.14, who placed at the center, was the most effective member toward connecting others and, consequently, she had more control of the interaction and information interchange within the blog community. Students, S1.10, S1.11, S2.19, S2.12, S1.6, S1.15, S1.2, S1.20, S1.4, S1.21, and S1.7, were also good connectors compared to their peers in the periphery. As an overall view, the blog was a very cohesive community; the majority of the participants had significant contribution while only four members had a marginal contribution, i.e. S2.17, S2.24, S1.23, and S1.7.

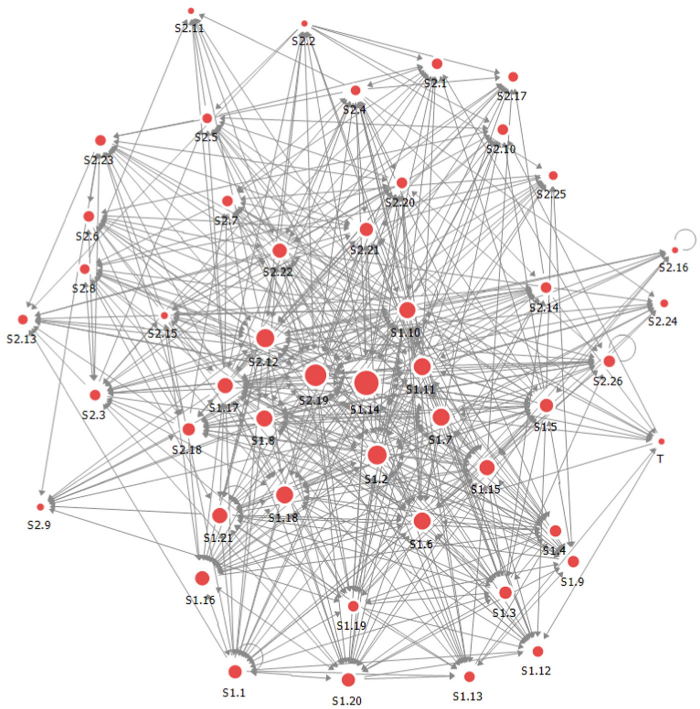

Fig. 3. Degree centrality map

Figure 4 shows the power centrality map of students' activities, which includes the connections of the members and offers a measure of the influence each participant had to the blogging community. S1.14 was the most influential and powerful student. In addition, a large group of teachers that are placed near the center of the map (i.e., S1.10, S1.11, S2.19, S1.6, S1.15, S1.2, S1.20, S1.4, S1.21, and S1.7), were also very active, members in the community; they had many ties and connections to other powerful participants. On the other hand, as moving to the periphery, students were less powerful and important community members. For example, students S2.17 and S2.24, who did not publish any comment to other blog articles, and S2.5, S2.11, S2.14 had a marginal contribution to the community by uploading very few comments (2–3 posts).

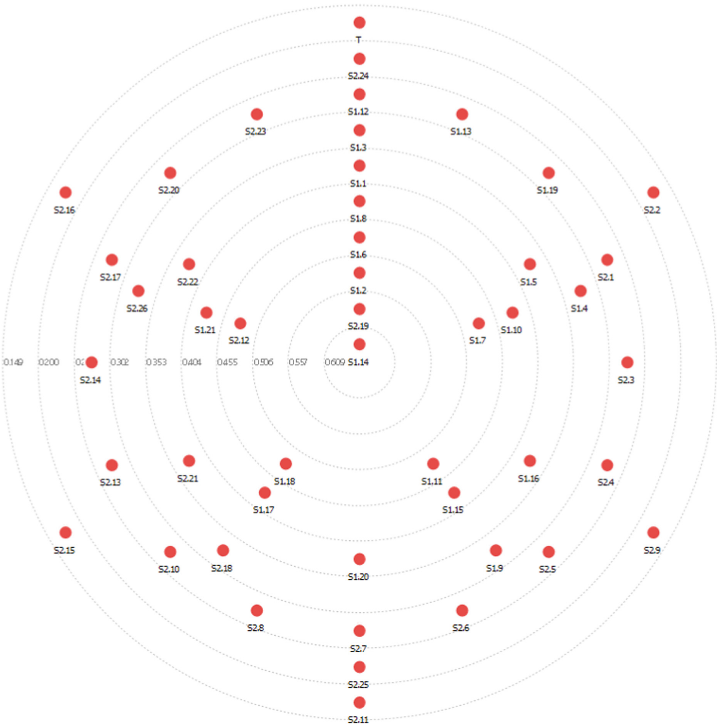

Fig. 4. Power centrality map

5 Conclusions and Future Work

This study reported on students' on-line academic writing through blogging in the context of a post-graduate course. Our analysis has shown that, by publishing their academic articles on the course blog, the students had enhanced opportunities for managing individual work, peer feedback and interaction, supportive dialogue and reflection, sharing ideas, critical thinking and metacognition, all having a positive impact on the quality of academic writing. The majority of the students demonstrated enhanced interest and they were actively engaged into the community activities that were spontaneously emerging within the course blog (uploading articles and postings, supporting dialogue and contributing to discussion topics, interchanging ideas, sharing content and resources, shaping new topics of interest, etc.). Confirming existing research findings [16, 18, 21], our results provided supportive evidence that on-line academic writing, embedded in higher education through course blogs, can promote students' reflective engagement, scientific research, critical thinking as well as the development of writing skills as active members of an on-line community.

The findings of SNA provided important information about the structure and the cohesion of the blog community, the student groups that developed therein, student connections and information flow, as well as the power and the influence each participant had within the blog community of inquiry. SNA revealed that the instructor was not the central member in this on-line academic writing program. Our findings provided a promising evidence of a decentralized learning community, where the learners had enhanced control and motivation to shape their contribution by adopting a continuous and dynamically evolving presence in the course blog.

In addition, SNA findings revealed differences in students' engagement with regards to the interactive and collaborative part of the on-line academic writing project. Three main groups of students were recorded according to their contribution to the information flow, the influence and the power they had within the blog community: (a) the students leading discussion and facilitating dialogue in the course blog through posting comments, questions, criticism and suggestions, (b) a large group of students that were good responders and connectors, in particular between students from different classes, and (c) a group of five peripheral members, who had no visible interaction with peers in the blog since they published very few comment postings.

Despite that this study is limited by the specific sample and the context of implementation, it has shown promising results regarding the application of blogs in on-line academic writing. Research outcomes could guide the design and the implementation of future interventions in higher education settings, as well as ongoing research in this area. However, the outcomes presented in this paper need further investigation and empirical testing to enhance the validity of SNA. Our current efforts are directed towards combining SNA results with qualitative data of content analysis regarding students' on-line discourse by using the schemas of Community of Inquiry and the Learning Presence. We expect thus to reveal more information about students' cognitive and learning presence as well as the role of self-regulation and co-regulation in on-line academic writing through blogging [25, 32].

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The Design of the RU EU? Game: A Game-Based Approach to Help Students' Exploring of European Identity and Values

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Abstract. The Erasmus+ funded RU EU? project aims to develop an innovative online game, the RU EU? game, that will help students across Europe to develop a better understanding of their own National and European identity and values, as well as those of others, and to challenge them about their attitudes and prejudices by tackling problem solving dilemmas relating to identity. It is hoped that the game will provide an engaging platform for young Europeans to confront some of the complex and confusing issues surrounding National and European identity at a time of change and increasing tension across Europe. The current paper describes the early stages of the game development life cycle for the RU EU? game. Definitions of and theory about European identity are presented since these will help to provide a rigorous theoretical underpinning for the game. We also provide a short account of the literature and resource reviews and the User Requirements Analysis, the early design tasks that have helped to guide our thinking about the game. Finally we consider our current thinking about the game itself.

Keywords: Educational games · User requirements analysis · European identity · National identity

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1 Introduction

In the last 15 years educational games and gamification have drawn an enhanced interest of academics, educators, practitioners and business professionals in domains as diverse as education, professional development, human–computer interaction, and health. Educational games are generally designed to promote learning in a specific discipline or subject area, to expand concepts and knowledge, to reinforce personal or professional development, to assist learners towards enhancing a skill or changing an attitude [4, 6, 7, 16, 31].

In this context, educational gaming is regarded as an active, problem-solving, situated and social form of learning, where learners reflect on their own experiences by receiving immediate and differentiated feedback. Findings from independent research studies strongly suggested that educational games have positive effects in both students' motivation and learning outcomes [4, 5, 13, 19, 20].

This paper reports on the design of the RU EU? game. This work is supported by and implemented in the context of the Erasmus+ funded project. The main objective of this project is to develop an innovative online game (the RU EU? game) that will help students across Europe to develop a better understanding of their own national and European identity and values, as well as those of others, to examine and reflect upon the impact of their own identity and values on their interactions with others, and to challenge them about their attitudes and prejudices in tackling problem solving tasks involving national and European identity. At a time of change across Europe, it is very important to try and understand why European citizens have very different views of themselves and others and what motivates these differences. It is hoped that the RU EU? game will provide an engaging platform for young Europeans to explore their views about some of the difficult issues that arise relating to National and European identity.

Games are typically highly engaging but have also been increasingly used to assist learning. Games are thought to be especially useful in tackling ill-defined problems [19] for which there is not one unique solution, but where there are many possible subjective opinions about the issue. Since understanding EU identity presents this kind of challenge it was thought that a game-based approach would provide an appropriate means of supporting young people in their exploration. Moreover, since games are highly engaging and familiar to young people, it was thought that these "digital natives" would find a game-based approach to exploring their identity and values highly attractive [28].

In this paper we present the design framework of creating the content and scenarios of a new educational game aiming to engage university students and promote their thinking about the European Identity. Our critical review of the literature provided a background to definitions and measures of European Identity which will underlie the game. We will also provide a short account of the Game Development Lifecycle, an outline of the literature review, the resource review and the user requirements analysis, the early design tasks that will help to clarify aspects of the game content as well as identifying player needs and requirements. Finally, we will present a first example of game scenario regarding of EU identity.

2 Theoretical Framework and Literature Review

2.1 Background to European Identity

In building a game about European Identity it is obviously important to ground the game firmly in a clear understanding of theories about European identity. The European Union is a confederal union of sovereign states, with a strong economic focus, that includes 28 member states and a combined population of over 500 million people. Dedman claimed that the origins and aims of the EU were quite clear [8]: (a) to avoid the conflicts that devastated Europe during the preceding decades and (b) to create an ever closer union. To date the EU has been successful in these aims. The traditional enmity between states has been replaced by a strong set of interrelated social, political and economic relationships.

Since the 1950s the EU has consistently grown in both size and operating remit, with the 1993 Maastricht Treaty establishing the current EU and creating a common citizenship. The closer themes of Union were further developed in the early days of the 21st Century, with a proposed constitution.

However, it seems that the EU, this experiment in Europe, is under challenge with several members wishing to see the membership changed or to alter the pace and focus of the changes that the EU is causing/requiring among member states. Cries of 'sovereignty' and 'identity' are raised with terms like the 'nation', 'our people' and 'us' and 'them' being employed to challenge the idea of a greater Union. Furthermore, many member states have witnessed the rise of anti-EU political parties, who seek removal of their member state from the experiment. Mendez, Bachtler and Wishlade argued that "the politics of European identity in Europe has become more salient following the recent economic and migration crises which have fuelled a rise in nationalist and anti-EU sentiment across Europe" [26].

The lack of development of a sense of European-ness among many member states is clearly reflected in research conducted throughout Europe [22, 23, 32, 34]. It appears that identity remains rooted in the national rather than the European, and the European Experiment is under challenge as a result. As the EU itself states "there is a need to deepen further the discussion on the future of Europe on what kind of Europe citizens want, also stimulating new forms of civic participation whilst reinforcing those existing" [12].

In an age of uncertainty about Europe there is a need to increase civic and intercultural understanding. Since young people will play a key role in the determining the future of Europe, it is especially important to find out what they think and how they can work together. There is increasing recognition of the role and impact of identity and values on the problems that are leading to this state of uncertainty in Europe. However there is much confusion in our thinking about identities and, while recognising that identity is important, most people find the construct difficult to understand.

2.2 Definitions of European Identity

While it is important to establish an agreed definition of European Identity, this is a contested and fluid concept that is understood (and measured) in different ways. It is acknowledged that National and European identity should be viewed as multidimensional since there are several components that contribute to these constructs. What it not so clear is how we should conceptualise these multidimensional constructs and a number of models have been proposed, including a cross cutting model, a Russian dolls model, a separate identity model and a marble cake model.

Cross Cutting Model. This suggests that national and or European identity overlap but not for all individuals. In addition not all members of an ethnic group may identify with their nation and or Europe.

Nested Model. The nested model or Russian dolls model proposes that smaller collective identities (local) are part of larger (national) or even larger (European) identities.

Separate Identity Model. The separate identities are separate if individuals in different identity groups do not overlap.

Marble Cake Model. This model proposes that the different identities are intertwined in such a way that it is difficult to separate them.

2.3 Components of European Identity

The design tasks were important in helping us to refine and confirm our understanding of the key Components of European identity, identified by Van der Zwet and Leith as follows [36]:

1. *Functional/instrumental* considerations regarding the costs and benefits of European integration;
2. *Value-based* considerations that relate to shared beliefs and norms often expressed through political institutions;
3. *Cultural* considerations which are often a more emotive identification to Europe as a shared cultural entity; and
4. *Biological/geographical* considerations which are more ethnic driven identification markers

Designing the game using these components of identity will ensure that the game has theoretical integrity with respect to European identity.

2.4 Measuring Nationalist/European Identity

As well as helping to clarify our working definitions and components of EU identity, the literature review also identified papers addressing the measurement of attitudes to Nationalist and European identities. This is important since at various stages in the game, players will be asked about their own attitudes to National and European identity. The aim of the game is not so much to change players' attitudes to the EU, to be more positive or negative, but to provide them with a richer understanding of identity on which to base their decision making and problem solving.

An easy-to-administer measure of attitudes to the EU is the evaluative space grid [21, 24]. This grid consists of a 5 $\times$ 5 matrix of cells, with the x axis representing positive attitudes toward the European Union and the y-axis representing negative attitudes toward the EU. Both are measured on a 1–5 scale with 1 meaning ‘not at all’ (positive or negative) and 5 meaning ‘very’ (positive or negative). Participants are asked to assess their positive and negative attitudes towards the EU simultaneously. The score of interest is the difference score which can range from 4 (‘fully positive evaluation of the EU’) to −4 (‘fully negative evaluation of the EU’) which provides a simple explicit measure of attitudes to the EU. This would be a simple and easily administered measure to assess attitude change before and after playing the game.

The ‘Moreno’ question is a very simple way to measure European identity, based on one question with 5 different response options [27]: ‘Do you in the near future see yourself as: (1) (nationality) only; (2) more (nationality) than European, (3) equally (nationality) and European; (4) more European than (nationality) or (5) European only?’. This question clearly addresses an individual’s perception of the balance between national and European identity, emphasising which is relatively more important to them. This indicator can be considered a self-identification (cognitive) measure as opposed to an affective measure of identity. It may be useful to administer this as part of the “balance” scenario.

Methodologically questionnaire survey methods have been used most widely to measure European identity, with the Eurobarometer [11] the best known and most widely used of these. Eurobarometer is a series of public opinion surveys conducted regularly on behalf of the European Commission since 1973. These surveys address a wide variety of topical issues relating to the European Union throughout its member states. The Standard Eurobarometer questions include those that measure: attitudes toward EU institutions, attitudes toward major topics concerning European affairs, public awareness of the EU, people’s satisfaction and expectations regarding the quality of life in the EU, and how citizens of European countries perceive the other EU countries. The advantage of the Eurobarometer is that, because it has been widely used across the different EU countries since 1973, the results can be address cross cultural differences as well as changes across time.

Mendez, Bachtler and Wishland [26] also identified a measure by Isernia et al. [18] that looks at different components of European identity, including geographical belonging, whether one thinks of oneself as a citizen of Europe, both now and in the future, the balance between thinking of oneself as a citizen of one’s own country but also as a citizen of Europe. The survey also asks about emotional identification with Europe with respect to attachment to Europe, closeness to Europe and pride in Europe. These questions address the cognitive and emotional identification, but also reflect some of the “content” of EU identity questions.

3 Game Design Methodology

Existing research in serious games design revealed the importance of two critical factors that support active learning and knowledge construction: (a) learning should be situated in an authentic context, and (b) the learners should have the control of both the game and their learning process. In addition, exploratory learning, problem-based learning and inquiry learning have been noted as critical design factors in educational games. Kenny and Gunter [20] explored complex learning goals and argued that learning content within a game should be highly related to the game's narrative elements. Amory [2] presented a constructivist theoretical framework to support educational games development based around the notion of interrelated components, i.e. units that have mutual dependencies and relationships. Arnab et al. [3] proposed a new model for the analysis and design of serious games, named Learning Mechanics-Game Mechanics, which is based on the idea of reflection on the various pedagogical and game elements in an educational game.

The creation and implementation of the RU EU? game will adhere to the development process of the game development life cycle (GDLC). In the context of games development, various GDLCs have been presented in the literature with the majority conforming to similar stages in the development process. These phases of development normally adhere to areas associated with the prototype and pre-production of the game, its development and testing in addition to its final release [29]. For example, Hendrick's [15] proposed five stages of game development where the prototype phase involves working on the initial design of the game, creating the design document, developing the game, undertaking sufficient beta testing prior to the game being released.

In contrast, an iterative approach towards game design has been proposed by Doppler Interactive [25] where the development stage of the life cycle is predominately dictated by the evaluation of the game. If the build for the game is not satisfactory then it is redeveloped and re-evaluated. The MDA framework proposed by Hunicke, LeBlanc and Zubek [17] provides an overview of differing perspectives on how a designer and player view a game. It posits that designers should initially focus on the aesthetics of a game then work backwards towards the dynamics and mechanics. In contrast, players at times view games via their experience of the mechanics, dynamics and aesthetics implemented by the designer.

In the context of game design and development, it can be argued that there are four fundamental elements that constitute a game namely: aesthetics, mechanics, story and technology. Schell [30] refers to this as the "elemental tetrad" game design framework. The aesthetics of a game relate to how the game looks, in terms of layout and design of levels and assets. This is an important aspect of game design as it can relate directly to the player's immersive gameplay experience. The RU EU game will be designed to ensure that there is a high degree of immersion and flow within the game. Gameplay is a fundamental component of game design. From a rudimentary perspective, gameplay can be defined as "the overall experience of playing a game" [14, p. 847]. In conjunction with the aspect of gameplay is the notion of game mechanics that define the rules of games, the objectives of the players and what the criteria for success and failure is [1, 14]. Story relates to the sequence of events that unravels during the course of a game and can be prescripted, branching or emergent [30]. Technology relates to the various mediums that make the game possible to play. For example, this could include the computer itself in addition to input and output devices.

The MDA approach towards game design will be applicable to the development of the RU EU? game; this will initially start by considering the experience of the player, the game dynamics and aesthetics. The various game scenarios will be considered from the perspective of the gameplay in addition to the rules of the game. The game will be predominantly narrative based as the player will adopt the role of a research journalist carrying out a number of assignments relating to European identity and values.

4 Preparation Tasks and Game Design Activities

The RU EU project is still in the very early stages of game development and, during this time, the focus has been on carrying out the initial design activities for the game. Figure 1 shows a flow-diagram of the game design processes: literature review, resource review and user requirements analysis. These early design activities have helped us to refine and confirm our understanding of the key Components of European identity and to identify issues relating to national and European identity and values that can be developed as scenarios in the game. It has also been important to consider features of the game and the main game activities and to contextualise the context of the game development.

4.1 The Literature Review

The systematic literature review aimed to identify relevant research on Europe and European identity that could be used to provide a firm academic underpinning and evidence base for the game and game activities, especially in developing the content for the game scenarios. The systematic literature review helped to confirm that important topics to consider in developing the game include definitions of Europe, identity and European identity, components of European identity, challenges to European identity,

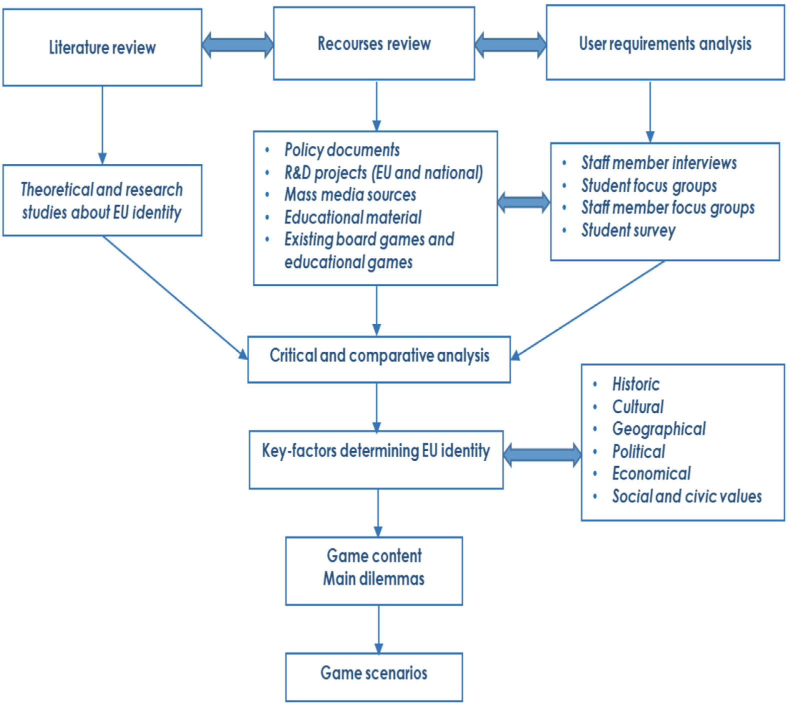

Fig. 1. Flow-diagram of the game design processes.

influences on European identity, the balance between national and European identity, differences in EU identity between member states and changes in EU identity across time. Further details of the results of the literature review can be found in Sim et al. [33].

4.2 The Resource Review

The resource review aimed to identify and collate existing materials and resources, both paper and pencil and e-learning resources that are currently using in educating young people about national and European identity and values [9, 10]. In addition to academic resources, newspaper headlines, audio/video extracts/snippets from TV and radio programs and newspapers were identified which could be used in the game content in presenting the main ideas about EU identity. For example, in explaining why he backs a chance for UK voters to consider the terms of the Brexit deal, Patrick Stewart, the leader of the campaign, recently said: "*What I am motivated by is history and emotion*" [35].

The resource review has also studied existing entertainment games and serious games where politics or national and European identity are relevant. Examples include: Democracy, a government simulation game where the player takes on the role as the president or prime minister of a democratic government in charge of policies in the areas of tax, economy, welfare, foreign policy, transport, law and order and public services; Papers Please (https://papers-please.en.softonic.com) is a puzzle video game where the player takes the role of a border crossing immigration officer in the fictional dystopian Eastern Bloc-like country of Arstotzka, where there are tensions between this country and neighbouring states; Bad News (https://www.getbadnews.com/#intro) is a fake news video game that aims to "vaccinate" players against misinformation, where players take on the role of fake news producers and score points by winning followers for their conspiracy theories and angry tweets. The content of these games and gamification mechanisms used will be examined to assess whether they are useful.

Consideration of these resources will help to provide content and a context for the game development, but will also help to ensure that the RU EU game differs from currently available resources.

4.3 The User Requirements Analysis

The User Requirements Analysis aims to ensure that the game is firmly based on the needs of prospective users. The User Requirements Analysis included: (a) staff interviews (15 participants from partner institutions), (b) student focus groups (25 participants), (c) staff focus groups (20 participants), and (d) student survey (200 participants). Both qualitative and quantitative data from prospective users of the game were collected to ensure that the game is based on realistic issues related to national and European identity that are of concern to educated young Europeans and other key stakeholders.

These tasks have helped to provide useful quotations that could be used in the game content. For example the following quotations, extracted from personal and focus group interviews with students (S) and staff member (T), provide differing perspectives on commitment to Europe:

S: *"Europe really does not impact on me in my day to day life. I don't give it a second thought."*
S: *"EU has a positive impact on me. People are free to travel across countries, to study or work in a different country, to have a common currency."*
T: *"I think Brexit made me feel more European."*
T: *"The key elements of the European identity as a concept are democracy, solidarity, equity, human rights and respect of differences among people. These elements are European and shape a common political and cultural identity, rooted in the Enlightenment."*
T: *"I think there's a core of countries that feel more European than others. And that's in central Europe, around Germany, Denmark, the Low Countries."*

Table 1 summarises the main findings of our analysis in terms of main dimensions of EU identity, factors and indicators.

Table 1. Key dimensions and factors of European Identity

Dimension	Factors	Themes
Historic	Common past The middle ages The reformation The enlightenment The industrial revolution The second world war The EU unification process	European history National histories Local/social history The EU history
Cultural	Cultural roots and values European languages Literature, philosophy, science Arts, music, architecture	Culture notions and symbols of European integration
Geographical	Nationalism vs hyper-nationalism North vs south countries	Migration
Political	Political integration, democracy EU citizenship Solidarity among Europeans	Strategic policies
Economical	Collaboration, common currency Competitiveness Sustainable and inclusive growth Employment and mobility	Digital economy and globalization Green economy Research and development
Social and civic values	Humanism and progressive values Environmental awareness Respect of cultural, linguistic and religious diversity	Poverty and social exclusion Climate change Environment protection

5 Developing Ideas for the Game and Game Content

The game is now moving into stage 2 of development where we are fleshing out the original proposals for the game and considering how the learning outcomes for the game will be mapped onto appropriate game mechanics and activities.

5.1 Educational Objectives for the Game

The four main educational objectives for the game are similar to those spelled out in the original project proposal for the RU EU? game.

Knowledge Dimension. Players extend and test their knowledge about Europe, European customs, values and traditions. There are a number of online educational materials that could be adapted for use in this game [7, 8].

Attitudes Dimension. The game players examine their attitudes to national and European identity. Players' responses will be used to match them up with other players who have different attitudes, to take part in the collaborative problem solving scenarios.

Application Dimension. Players solve challenging (ill-defined) problems surrounding issues that are rooted in notions of identity. This is the main substance of the game where players encounter problem scenarios that tackle some of the difficult dilemmas facing young Europeans today. Many of these dilemmas are fundamentally rooted in conflicting national and European identities and values and the aim of the dilemmas is to encourage players to consider and understand both sides of the argument in order to progress in the game.

Social Dimension. Players (as teams) collaborate in tackling the problem solving and decision making scenarios. Our current thinking is that this element of the game will be located in the student support materials attached to the game.

5.2 Overarching Narrative

The suggested overarching narrative for the game is that of a research journalist working on a local newspaper. The journalist's brief is to look at European identity and values and (s)he will carry out a number of assignments reporting about various issues that local readers of the newspaper are struggling with, relating to European identity and values. The issues correspond to the scenarios in the game and, for every issue, the journalist will carry out research to write a short article at the end of mini-game play. As a good journalist, pros and cons from various resources will be reflected in these articles. In writing the articles the journalist has access to a range of resources, including statements from interviewees, audio and video clips, twitter-feeds, magazine headers and television headlines.

5.3 Game Scenarios

The design tasks, including the literature review on European identity, have helped to suggest the following game scenarios, all based on key issues relating to European identity:

1. Balance between national and EU identity
2. Who is European anyway?
3. Rights of EU citizens – the right to work
4. Changes in EU identity over time
5. Rights of EU citizens – immigration

Table 2. Partially completed template for the immigration scenario (scenario 5).

Learning Objectives: To be exposed to and understand different viewpoints; to understand and appreciate the differing opinions available around migration; to understand why people may feel the way they do.
Tasks: To interview a range of stakeholders in the immigration debate: immigrants, employers, local community leaders (pro and anti), public figures and consider wider public perceptions.
Goals: To evaluate and rank in importance the key positions put forward by a number of Non Player Characters and game sources (based upon an agreed classification scheme) and prioritize statements/materials that will be included in the final journalistic output.
Feedback from the 'editor': Each section of the overall scenario will involve (automated) feedback from the 'editor' that will illustrate where the emphasis of the prospective journalistic output is going and suggest other areas that could be considered and used to challenge the direction and thinking of the individual. The automated feedback is based upon a set of agreed "stakes" that partners have identified. Stakes are the main underlying reasons that motivate how people think and feel about the EU. It is argued that the statements that the interviewees make about the EU are motivated by these stakes. The stakes are as follows: Democratic Human rights and freedoms; Locus of political control; Economy/money/jobs; Equality and Fairness; Security; Change and Uncertainty; Shared Culture and History; Emotions. Each statement will be implicitly categorized as representing one of these stakes and the feedback will complement the player for including what he has done but also indicate what he has omitted. For example: "In your draft report you have emphasized the following aspects of EU identity: Democratic rights and freedoms, the economy/money and jobs, Equality and Fairness and Change and Uncertainty. But what about Locus of political control, Security, Shared Culture and History and Emotions."

In the scenarios the journalist will carry out the 5 different assignments to address the briefing. In each case, he will interview a range of stakeholders, both with pro and anti-EU attitudes, such as politicians and other public figures, local community leaders, members of the public, about their views on the different scenarios. The journalist will have conversations with non-player characters and will examine audio and video extracts as well as twitter accounts to compile the resources that he will use to create his report. The aim is to present a balanced and unbiased report.

Partners have created a template to be used for creating each scenario that will specify a number of conditions including: what the scenario is about; what the learning objectives are; what tasks or assignments need to be carried out; where the tasks are carried out; what skills are acquired; at what point in the game this scenario will take place; what tools and resources are required. For example, Table 2 shows a partially completed template for Scenario 5 (the immigration scenario).

Scenario 5. Rights of EU citizens –immigration. Scenario 5 will address the issue of immigration, an issue that has posed the greatest threat to the stability of the EU in recent years. This scenario will be developed in a similar way to the other scenarios, but it will also have a social dimension, since it will provide an opportunity for collaboration between students, both in the classroom discussions with their peers and via Skype discussions with peers of different nationalities.

6 Conclusion

This paper has described the very early stages of the game development life cycle for the RU EU? Game. We have argued that in order to support players in understanding EU identity in a valid and plausible way, the game requires a rigorous theoretical underpinning and for this purpose we have described the background, definitions and theory on European identity, as well as different views about how attitudes to the EU have been measured. We have briefly described how the game design tasks: the Literature and Resource Reviews and the User Requirements Analysis, have influenced our early ideas about the game and helped to populate the game content. We have defined the knowledge, attitudinal, application and social learning outcomes for the game, providing more detail on how the problem solving scenarios will allow players to apply their knowledge of EU identity. Over the next twelve months these early thoughts and ideas about the game will be extended and developed into the innovative online RU EU? Game.

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Building Critical Thinking in Higher Education: Meeting the Challenge

Facilitating Primary Student Teachers' Development of Critical Thinking Through a Nanotechnology Module

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Abstract. This study describes an attempt about facilitating primary student teachers to develop critical thinking through the implementation of a module regarding a modern scientific topic, namely Nanotechnology. Firstly, based on literature suggestions, we outline the specific skills and dispositions that are related to critical thinking. Secondly, we emphasize the salient features of the Nanotechnology content. Scrutinizing the Nanotechnology educational material that was implemented under the lens of critical thinking skills and dispositions, we seek to identify which tasks could have potential to promote critical thinking. On the one hand, findings indicate that skills such as analysis, explanation, interpretation and dispositions such as self-confidence and inquisitiveness could be promoted. On the other hand, we discuss that the need of enhancing or developing additional skills and dispositions may enlighten the design of future implementations.

Keywords: Critical thinking skills and dispositions · Nanotechnology · Primary student teachers

1 Introduction

The development of critical thinking (CT) is imperative, nowadays, since people are challenged to face complex situations, taking reasonable decisions and assessing alternative solutions critically [1, 2]. Consequently, students should promote their CT in order to be capable to dispute provided claims (e.g. by authorities), consider multiple perspectives and decide in responsible manner about the significance of modern scientific and technological progress to their life [3].

Furthermore, the rapid progress of science and technology in modern fields such as nanotechnology, raises concerns about the impact they may have on the environment, health and society. Addressing such challenges requires the development of students' CT [4]. In this regard, several research proposals describing inquiry–based learning environments have been published until now, aiming at involving students in topics associated with Responsible Research and Innovation (RRI) [5, 6].

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The purpose of this study is to identify the CT skills and dispositions that can be promoted during the implementation of a nanotechnology module to primary student teachers (PTs).

2 Theoretical Background

2.1 Inquiry Learning Environment for Promoting Critical Thinking

The various definitions of CT include aspects such as purposeful thinking, inductive or deductive reasoning, analyzing data or arguments, formulating inferences, justifying explanations, assessing the validity and the reliability of statements, making decisions or solving problems [3, 7, 8]. Furthermore, keeping in mind that “Human beings are more than thinking machines” [9], CT is associated with the attitudes or dispositions that someone has to demonstrate in order to be a good thinker [7]. Specifically, several dispositions have been identified: truth-seeking, self-confidence, willingness to plan, inquisitiveness, flexibility, cognitive maturity, open-mindedness, etc. [7, 9]. In brief, a critical thinker integrates both skills and dispositions into addressing successfully societal challenges.

In the context of Science, Technology, Engineering, Mathematics (STEM) education, specific aspects of inquiry teaching-learning environment are perceived as promoters of CT. Generally, inquiry-based learning is a form of active learning enabling posing questions and discussing problems or scenarios to students that have to identify research issues and questions in order to develop their own knowledge or provide their own solutions. The main learning outcome of this environment is students to be able to combine scientific skills (e.g. observing, classifying, analyzing data) with knowledge, reasoning and CT [10]. For example, the inquiry problem-solving strategy involves meaningful learning through real-world problems. It begins by presenting a problem and targets to a desired solution via a small-scale research [11]. Consequently, problem solving strategy is considered an appropriate approach for improving the CT skill self-regulation [12].

In addition, it is argued that a model-based inquiry environment promotes evaluation skills as it fosters students to think about the usefulness and credibility of models [13]. An inquiry collaborative learning environment, supported by the use of cooperative learning techniques such as the constructive controversy and the jigsaw method facilitates the development of self-confidence as well as open-mindedness dispositions, since students interact with each other within small groups, gather data, exchange divergent or similar ideas, review solutions, justify their own judgments [9, 14, 15].

2.2 Nanotechnology Education as a Platform for the Promotion of Critical Thinking

Nanotechnology means, literally, any technology conducted on the nanoscale regime having profound, practical applications in the real world [16]. Although no consensus has been reached so far, the nanoscale is placed within the range of 1–100 nm approximately. Within these dimensions, emphasis is being placed on the manipulation of individual atoms or molecules to extended atomic or molecular structures with submicron dimensions, in order to design and create new materials, systems and devices with novel properties for practical applications in nearly all aspects of our lives [16, 17]. These new applications, coming from the explosion of new ideas and discoveries, have the potential to form "a greener, more efficient and healthier world" [6].

The magnetic, mechanical, optical, electrical properties of the materials at the nanoscale gain major attention and speed up the progress of this field [4]. Most phenomena taking place at the nanoscale involve entities that are studied by chemistry (e.g. macromolecules) or biology (e.g. biological nanomachines such as viruses or individual cells), whose interactions are governed by physical laws. As a consequence, interdisciplinary teams of scientists and engineers are required in order advances to occur [18].

The coming era of nanotechnology has raised societal, ethical and health/safety issues. It is remarkable, that the emergence of new fields of research, creating debates concerning the risks and benefits of the new advances, is not so rare [19, 20]. In the case of nanotechnology, it is a matter in question what happens to the human body when it is infused with nanomaterials or to the environment when nanomaterials end up to natural resources such as to rivers or to lakes [16]. "Nanotechnology [..] demands not only public support but public skepticism and critical thinking as well" [20].

In the next paragraphs we pursue arguments concerning how the inclusion of nanotechnology to school curricula has the potential to promote students' CT skills. We stress how the abstractness of the nanoscale, the interdisciplinary nature of nanotechnology, the risks and benefits, emerging from this new field and the myriads of practical applications may justify the promotion of CT.

To begin with, due to the progress that has been made in the field of microscopy within the last decades, scientists and engineers has been offered the opportunity of entering the abstract nanoworld. Advanced microscopes such as Scanning Probe Microscopes (SPMs) and Electron Microscopes provide visualization to targets (viruses, molecules such as DNA, nanotubes) otherwise inaccessible [6, 21–23]. Nanoscale images created by advanced microscopes can provide some knowledge about how nanoscale entities look like. However, that kind of images can be misleading. SPM images often have artificial colors whereas some shades are added in order the object to be depicted as three dimensional as much as possible. This intrinsic imperfection of nanoimages raises some serious considerations. For example, "how do we know what is real when we see a picture of a nanoscale object?" [24]. We consider that this kind of questions can promote CT since learners need to assess the credibility of various nanoscale representations (electron microscope photographs, nanoimages, 3D models and computer stimulations) in order to form accurate mental models about the abstract world of the nanoscale. In addition, the misleading factor of nanoimages can serve as an appropriate context for someone to promote the dispositions of truth-seeking and open-mindedness, which have been acknowledged as kinds of the CT dispositions [9]. Truth-seekers should evaluate new information and evidence and an open-minded learner should be able to consider that different nanoimages could trigger divergent explanations about the same nanoscale entity.

The next kind of argument derives from the inherent interdisciplinary nature of nanotechnology. "Interdisciplinary innovation is primarily about team-work, where members of the team bring different skills and perspectives which together bring added benefit" [5]. On the one hand, nanotechnology represents a modern subject where the demarcations of the traditional fields are blurred, resulting in the collaboration of scientists. On the other hand, it has already been discussed that students can hardly become successful in their real life by learning content knowledge from isolated disciplines [25]. In this direction, it is pointed out that "Students need to develop skills in critically evaluating and integrating knowledge across a variety of fields in order to solve unique problems that arise in the ever-changing economic and global environment in which they will be pursuing their careers" [26]. Following the above consideration open-mindedness can be promoted within the interdisciplinary nature of nanotechnology, in view of multiple perspectives from a variety of fields.

Moreover, the third argument comes from the need of promoting RRI [5]. In brief, RRI takes into consideration effects and potential impacts of new technologies on the environment and society. The advent of nanotechnology raises dilemmas concerning the benefits and risks for the environment and citizens' health and safety that emerge due to the integration of nanomaterials to everyday products [6]. It is argued that the exploration of socio-scientific dilemmas fosters students to develop CT [27]. Therefore, students are challenged to overcome, open-mindedly, their personal biases, to gather, analyze and interpret data from multiple perspectives in order to make a decision whether an innovation is meaningful or becomes a menace for their life. Furthermore, we stress that RRI will offer opportunities for promoting cognitive maturity CT disposition, if concrete context-based approaches are developed, taking into consideration different opinions, ethical norms that involve multiple stakeholders and entities [9].

The last kind of argument regards research suggestions concerning factors that increase students' engagement in science. On the one hand, the introduction of a modern breakthrough conforms to this statement. On the other hand, a distinguishable feature of nanotechnology is that there are myriads of applications available on the market which increase with an unprecedented rate. In particular, while in 2005, 54 nano-related products were commercialized in the market, this number increased to 1.628 by 2013 [6, 28]. How do the above data correlate to CT? To answer this question, we should take into account the dispositions that have been defined and are considered vital for fundamental CT [9]. We advocate that inquisitiveness is a kind of a CT disposition that can be promoted when students are introduced to modern advances as students' intellectual curiosity and desire for learning can be boosted. In this direction, a study has revealed some issues regarding why nanotechnology topics may provoke secondary students' curiosity for exploration. The novelty of this subject in combination with the plethora of applications had been defined by students themselves, being the factors that can motivate them and provoke further their inquisitiveness in order to explore the new field of Nanotechnology [29].

Until now we can hardly find any study aiming at measuring CT skills in the context of an intervention regarding a particular nanotechnology topic. However, studying published research papers relating to CT and being based on the above argumentation, we can identify relevant aspects. One study describes the implementation of a nanotechnology module about the modern application of Light-Emitting Diode (LED) by using constructivist pedagogy [30]. Although not explicitly alluded to by authors, some evidence regarding CT can be found in this study. For example, some of the students at the beginning of the course showed reluctance to take control of their own learning and they stressed their deficiency to conduct and explain the data produced from an experiment or to pose relevant questions. On the contrary, when the implementation was completed, students emphasized that the student–centered pedagogy in combination with the modern topic of LED increased their eagerness to seek knowledge about other advances of science [30]. In addition, we should note that the vast majority of the research efforts regarding the introduction of nanotechnology to students of all grades include instructional practices that take place in an inquiry–based learning environment. Arguments are associated with the statement that inquiry–based instruction that emphasizes the role of evidence and scientific explanation can promote CT skills, being necessary for scientific inquiry [4, 31].

According to the above-mentioned discussion, we ascertain that research on how nanotechnology can be a vehicle for promoting CT to students is in its infancy. Based on this statement, in this paper we present a module that was designed and implemented for introducing concepts and phenomena of nanoscale. Within the educational materials of the nanotechnology module we seek to identify CT aspects (skills or dispositions). Specifically, we aim at answering the following question: "Which CT skills and dispositions are expected to be developed by engaging PTs in specific educational tasks concerning nanotechnology content?".

3 Research Methodology

3.1 The Context of the Research

The nanotechnology module was designed in order to educate PTs during a one-semester course. It consisted of six units with two-hour duration each including interdisciplinary concepts and phenomena that provided opportunities for identifying relations among Science, Technology and Engineering. Specifically, PTs were introduced to the interdisciplinary concepts of: (a) size, (b) size-dependent properties, (c) tools, (d) Science-Technology-Society and (e) models [22]. Concerning the concept of size, PTs classified biological and technological objects (e.g. cells and nanopores) into macroworld, microworld and nanoworld, from largest to smallest. Moreover, they used observation tools such as optical microscopes and discussed how they contribute to the study of these three worlds. Regarding size-dependent properties, the concept of superhydrophobicity was introduced. PTs examined how the nano-sized structures of natural and technological materials (e.g. acacia leaves and nano-wood respectively) affect their wettability and their self-cleaning. Concerning Science-Technology-Society participants investigated how nature inspires scientists and engineers to create applications that solve everyday problems (biomimicry) e.g. superhydrophobic textiles. Furthermore, they explored how nanotechnology can positively contribute to the potable water shortage problem in Africa via nanofilters. Upon models PTs were introduced to the nature and role of models and to modeling practices as well. For instance, they created models of the nano-structure of the acacia leaf, they presented their own models and discussed how they concluded to the particular representations.

3.2 Data Sources

The sources for this data analysis were six lesson plans, eight students' worksheets and a poster. The lesson plans describe in detail the teaching and learning activities e.g. teacher's questions and participants' tasks. Worksheets include motivating questions for inquiries, tasks for supporting observation, data collection and a model creation as well. The poster is about the nature and role of models and was used as a reflection tool in the modeling process and the related discussion.

3.3 Data Analysis

This research follows a top-down qualitative content analysis [32]. Specifically, the description of the educational tasks were analyzed and were matched to the "list of mental skills and habits of mind" that promotes CT [9]. This proposal is the result of a two-year collaboration of 46 experts from different scientific fields (humanities, science, social sciences and education) who implemented the Delphi Method, under the authority of Peter Facione. More specifically, this framework-proposal was chosen as the most appropriate one because it compiles in a complete and integrated manner, both skills and dispositions, their descriptions as well as related fire-up questions that are expected to promote CT. As a result, we were able to identify the specific CT skill or disposition that was promoted by each task.

Six core CT skills and seven dispositions are suggested along with corresponding fire-up questions that ignite CT. The core CT skills comprise: interpretation, analysis, inference, evaluation, explanation and self-regulation. The dispositions include: truth-seeking, open-mindedness, analyticity, systematicity, self-confidence, inquisitiveness, cognitive maturity [9].

In order to identify the particular CT skill that is promoted within the educational material we have matched the fire up questions of CT skills listed in [9] with the description of each educational task of the nanotechnology module. In the following, we present two illustrative questions that trigger each CT skill.

- "What is the best way to characterize/categorize/classify this?" or "How can we make sense out of this (experience, feeling, statement)?" (Interpretation skill).
- "Why do you think that?" or "What is your basis to saying that?" (Analysis skill).
- "What does this evidence imply?" or "What are the consequences of doing things that way?" (Inference skill).
- "How credible is that claim?" or "How confident can we be in our conclusion, given what we now know?" (Evaluation skill).
- "How did you come in that interpretation?" or "How could you explain why this particular decision was made?" (Explanation skill).
- "Before we commit, what are we missing?" or "How good is our evidence?" (Self-Regulation skill).

We have acted in the same manner in order to identify which CT disposition is promoted through the nanotechnology module. Specifically, taking into account the detailed description of each disposition that is outlined in [33], we carefully examined the self-rating form consisted of 20 questions in order to identify correspondences between the seven CT dispositions [9] and these questions. Two illustrative questions for each CT disposition are presented below.

- "Was I courageous enough to ask tough questions about some of my longest held and most cherished beliefs?", or "Did I back away from questions that might undercut some of my longest held and most cherished beliefs?" (Truth-seeking).
- "Have I showed tolerance toward the beliefs, ideas, or opinions of someone whom I disagreed?", or "Have I tried to find information to build up my side of an argument but not the other side?" (Open – mindedness).
- "Have I tried to think ahead and anticipate the consequences of various options?", or, "Have I made a serious effort to be analytical about the foreseeable outcomes of my decisions?" (Analyticity).
- "Have I manipulated information to suit my own purposes?", or "Have I organized for myself a thoughtfully systematic approach to a question or issue?" (Systematicity).
- "Have I approached a challenging problem with confidence that I could think it through?", or "Instead of working through a question for myself, did I take the easy way and asked someone else for the answer?" (Self-confidence).
- "Have I read a report, newspaper or book chapter or watched the world news or a documentary just to learn something new?", or "Did I put zero effort into learning something new until I saw the immediate utility in doing so?" (Inquisitiveness).
- "Have I showed how strong I was by being willing to honestly reconsider a decision?", or "Have I attended to variation in circumstances, contexts, and situations in coming to a decision?" (Cognitive maturity).

4 Results

In Table 1, we present the CT skills, the sub-skills and the related fire-up questions deriving from the data sources.

Several tasks were implemented in order PTs to construct two criteria for clarifying the meaning (interpretation skill) of the three worlds (macroworld, microworld and nanoworld). Our aim was PTs to classify the three worlds according to: (a) the tools used for their observation, namely unaided eye, optical microscope, electron microscope and (b) the landmark objects of each world (e.g. ant, red blood cell, DNA). We focused on the following question "What is the best way to characterize the three worlds, macroworld, microworld, nanoworld?".

In addition, they examined data (analysis skill) from multiple sources in order to identify relations among concepts, descriptions and phenomena.

Table 1. Questions to fire-up critical thinking skills in the nanotechnology module

Critical thinking		Fire-up questions
Skills	Sub-skills	
Interpretation	Clarify meaning Categorize	What is the best way to classify the threeworlds, macroworld, microworld, nanoworld? What is the best way to characterize the three worlds, macroworld, microworld, nanoworld?
Analysis	Examine data	Why do you think some surfaces show the super-hydrophobic property?
Inference	Draw logically justified conclusions	Purifying dirty water with nanofilter, what are the consequences to human health and economy in Africa? What does this experiment about testing different size pores imply?
Evaluation	Assess credibility	Why do you think we can accept this model as an appropriate representation of these nanoscale objects?
Explanation	State the results Justify cogent arguments	How would you explain your reasoning about your classification of macroworld, microworld, nanoworld? You have concluded that the most effective water filter should consist of nanopores. How do you explain this conclusion?
Self-regulation	Self-correction Self-monitor	Before we create our model, what are we missing? How good is my evidence in order to teach my homegroup classmates about the super-hydrophobicity of plants and materials?

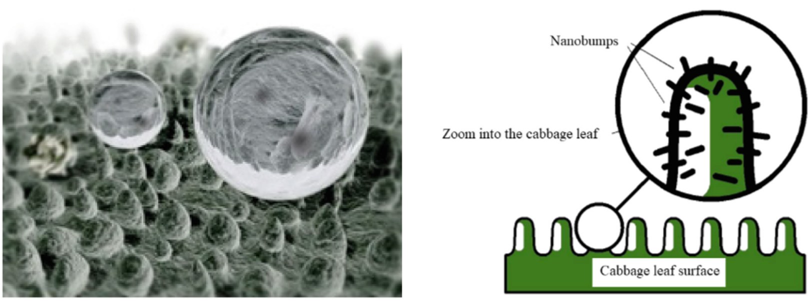

Fig. 1. Different representations of nanobumps (Retrieved from http://www.nisenet.org/catalog/lotus-leaf-effect)

For example, they identified the existing relation among the concept of superhydrophobicity, the nanoscale structures (nanobumps) and the self-cleaning phenomenon. Additionally, they conducted experiments observing on which materials the water forms spherical droplets and roll (cabbage leaf, nanotextile, etc.), as well as they watched videos and studied different representations of nanobumps (Fig. 1).

Furthermore, PTs were assigned to query the evidence concerning how nanotechnology research and innovation have the potential to solve global social problems such as the potable water shortage (inference skill). They were motivated by watching a video, presenting this social problem in Africa, to consider health and economic impacts on Africa citizens. In this context, they experimented on alternative technical solutions about the water purification sector. For example, they tested different sized pores filters concluding that the nanofilter is the most effective.

Throughout the module, PTs were assigned to present their constructed models of objects and phenomena before the whole class. They were encouraged to participate in interactive dialogues for assessing the credibility of the constructed models. For example, they created models in order to represent nanoscale landmark objects e.g. virus and DNA. Using the fire-up question "why do you think we can accept this model as an appropriate representation of these nanoscale objects?", PTs evaluated the credibility of the models having been constructed by other groups (evaluation skill).

PTs were asked to present a poster in order to explain the criteria that they created for classifying the three worlds, macro-micro-nano. During their presentation they were triggered to explain their reasoning about the classification once more (explanation skill). Additionally, we asked them to state the results of three different experimental tasks and furthermore to justify in a persuasive manner their own conclusion (explanation skill). The intended learning was PTs to be able to explain how the nanoworld affects the macroworld. Specifically, they were engaged in inquiry learning activities in order to study the viral infection, the lotus effect and the water nano-purification. For each case, they created a model (e.g. a model of virus infection) in order to explain how the objects and the phenomena of the nanoscale affect the macroworld of scale (Fig. 2).

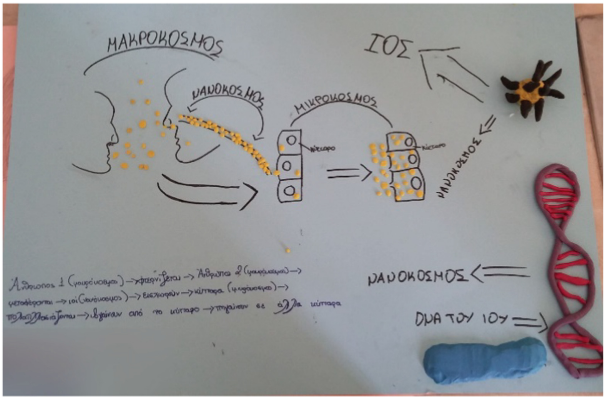

Fig. 2. A PT's model for representing how the nanoworld affects the macroworld: the viral infection case.

Concerning the self-regulation skill, we underline one of the most common learners' self-questions during the modeling practices: "before we create our model, what are we missing?".

In addition, we implemented the jigsaw inquiry collaborative method. Four expert groups as well as heterogeneous homegroups were formed [34]. Each expert group experimented with different super-hydrophobic plants and materials, sought for information and prepared their evidence in order to teach their own classmates back to homework about their expertise. During this process PTs were encouraged to think how good their evidence is.

In Table 2 we display the CT dispositions and the related fire-up questions in the nanotechnology module. In particular, we focused on a special characteristic of the nature of nanotechnology content, namely the misleading factor of nanoimages. More specifically, having already discussed that a model represents only specific aspects of the target (e.g. size, color, property), we sought to challenge them to explore the underlying truth perspective in several modes of nanoscale depictions (truth-seeking disposition). For example, three modes of visualizations were presented for the depiction of virus and of DNA helix: computer simulation, drawing representation and a video model (Fig. 3). Raising the question "how do we know what is real when we see a picture of a virus?", PTs become encouraged to seek the "best" knowledge in the given representations. In parallel during this kind of activity we opted to evoke them to be openminded that is, to acknowledge "It is important to us to understand that divergent representations could describe the same aspect of the virus".

Fig. 3. Visualizations of a virus and DNA (Left visualization. retrieved from https://www.youtube.com/watch?v=Rpj0emEGShQ, Right visualization retrieved from https://www.youtube.com/watch?v=PHp6iYDi9ko).

We should underline that during the lotus effect and nanofilter purification tasks, PTs were engaged in real world contexts e.g. superhydrophobic t-shirts in sports. As a consequence, they became curious for nanotechnology-related applications. For example, we started a discussion about "how could athletic shoes be superhydrophobic?" or "are there water flasks including nanofilter that we may use in our everyday life?". Moreover, we presented several nanotechnology products demonstrating videos and slides. We estimate that these teaching-learning tasks could really facilitate the development of the disposition of inquisitiveness concerning nanotechnology advances.

Table 2. Questions to fire-up critical thinking dispositions in the nanotechnology module

Dispositions	Fire-up questions
Truth-seeking	Was I courageous enough to ask questions what is real when we see a picture of a virus?
Open-mindedness	Have I showed tolerance towards the divergent representations of the virus that describe the same aspect of it?
Inquisitiveness	Have I read a newspaper article about how could athletic shoes be superhydrophobic? Have I read online sources whether there are water flasks including nanofilter that we may use in our everyday life?

5 Conclusions and Future Work

In this paper, we outlined some remarks about the subject of nanotechnology: (a) the abstractness of the nanoscale, (b) the interdisciplinary nature of this field (c) the need to promote RRI and (d) the myriads of applications. For each of the above-mentioned directions, we sought to identify which particular CT skills and dispositions could be developed through a nanotechnology module, having been implemented to PTs.

5.1 Direction 1: The Abstractness of the Nanoscale

One of the primary challenges that nanotechnology educators face when they train learners about this modern field regards the ability of inventing techniques in order to overcome the abstractness of the nanoscale. "The problem is conceptual and practical; objects and concepts at the nanoscale are hard to visualize, difficult to describe, abstract, and their relationships to the observable world can be counterintuitive" [35]. Studying the module with adherence to CT, several skills and dispositions were revealed. For example, the establishment of the two criteria (the corresponding landmark objects and the appropriate observation tools) in order PTs to develop awareness about the three worlds, led us to identify two subskills, the categorization and the clarification of the meaning of each world, that belong into the interpretation CT skill [9].

Having approached the nanoworld, we introduced one example of a counterintuitive phenomenon coming from the presence of nanoscale structures on the surface, i.e. the superhydrophobic effect. The drive-in question "Why do you think some surfaces show the superhydrophobic property?" dominated learners' inquiry, during which several hands-on experiments were conducted. Since PTs searched for relations between concepts and phenomena, we identified the analysis CT skill that could have been developed addressing this effect.

Furthermore, following research recommendations [36], another technique we implemented in order to help PTs to conceptualize the nanoworld was the use of multiple modes of representations. Drawings, computers simulations, video animations, 3D concrete models were used throughout the module. We paid attention to the identification of CT skills and dispositions, based on the crucial consideration concerning what we can learn when we study a picture of an abstract nanoscale object [24].

We discussed that a successful response to the above consideration promotes certain CT dispositions such as truth-seeking and open-mindedness.

5.2 Direction 2: The Interdisciplinary Nature of Nanotechnology

Nanotechnology is considered a highly interdisciplinary field. Its significance is indicated by statements such as “[interdisciplinarity] is a non–negotiable ingredient of nano-education” [37]. We can trace some features to our module that correspond to the interdisciplinary feature of nanotechnology. For example, landmark objects studied by biology were introduced (virus, DNA helix), concepts that derive from physics were defined (superhydrophobicity) and innovations from the field of technology were demonstrated (e.g. water filters, superhydrophobic wooden surfaces).

However, the interdisciplinary character of nanotechnology was not emphasized during the instruction. Our main goal was to help PTs realize that the nanoworld, though its small size, may have serious effects within the macroworld we experience every day. Thus, it remains an open question how we can build on the inherent interdisciplinarity of nanotechnology to facilitate learners’ CT. We plan to develop educational materials within our future implementations that will explicitly include the interdisciplinary feature of nanotechnology and seek to provide insights regarding the aforementioned consideration.

First priority in this direction could be the negotiation of the interdisciplinary content of the lotus effect that would clarify the interaction among Physics, Mathematics, Biology, Engineering and Technology. For instance, based on Physics, the phenomenon is explained through the hierarchical micro and nano-structure of the leaf’s surface. Mathematics are needed in order the dimension of the invisible structures and the contact angle between droplet and the leaf’s surface to be measured. Biology explains how the superhydrophobicity supports the leaf transpiration. Engineering and Technology addresses the idea of biomimicry for designing and producing applications that solve daily problems e.g. non-wetting and self-cleaning textiles [16]. Consequently, taking into account that the interdisciplinarity of nanotechnology can help students to estimate how different stakeholders (e.g. scientists and engineers) think about the same phenomenon, [9] we think that the disposition of open-mindedness could be developed.

5.3 Direction 3: Responsible Research and Innovation (RRI)

RRI has been established recently and is associated with the balance of risks and benefits that emerge from any new idea or discovery [5]. Having PTs participated in such RRI debates in classroom could foster their CT skills and dispositions about new fields of research.

We have not designed any task that would present to PTs the risks and at the same time the benefits of nanotechnology innovations to their health or to the environment. As a consequence, we have not researched for relevant skills and dispositions. In a similar manner towards interdisciplinarity, we raise the question “How can the perceptions of RRI, increased through the advent of nanotechnology, contribute to the promotion of the learners’ CT?”.

In order to answer this question, we plan to implement the Six Thinking Hats method [38]. According to this method, the color of each hat represents a different style of thinking about a particular subject. For example, the yellow hat corresponds to the benefits of the subject under inspection, whereas the black hat has to do with the difficulties, dangers and potential problems. This method has the potential to promote decision making, the understanding that more than one plausible explanation, options, risks or benefits are acceptable in some situations. Through this case, we plan to promote the PTs' cognitive maturity disposition. A particular nanotechnology topic, through which this method can be implemented could be the water nano-filters application.

5.4 Direction 4: The Myriads of Applications

Nanotechnology is a field whose innovations are increasing exponentially in multiple sectors, such as health, energy, electronics, transportation etc. We demonstrated those applications that are associated with learners' everyday life. We also encouraged PTs to experiment with some superhydrophobic surfaces (stone, wood, glass, fabrics) and water filters. These specific applications provided some real-world contexts. We expect that our option has the potential to develop the inference CT skill of learners, as we encouraged them constantly to elaborate on the consequences to human health and economy of the above applications (water filter). Furthermore, taking into account that the advances of science have the potential to excite PTs and capture their imagination [30], we argue that their disposition of inquisitiveness was supported.

Apart from the above four directions that relate to nanotechnology content, we should also note two features of the learning environment that can promote learners' CT. The first one relates to the model-based inquiry environment we set up for approaching the unfamiliar nanoscale objects and phenomena. Throughout the units, PTs had not only to use models as tools for obtaining information about the nanoscale phenomena and construct concrete models, but also to use them as communication tools in order to demonstrate the results of their exploration to other groups of PTs. Throughout this process, several CT skills were identified. For example, in the model construction stage, we identified the self–regulation CT skill when we encouraged learners to think about the "missing part" (Table 1) before they concentrate on the specific aspect of the target which they decided to represent.

The second feature associates with the collaborative learning environment which, as having been already discussed, can foster certain CT skills and dispositions. The jigsaw method is a representative example of forming an environment in which PTs have to develop a high team spirit in order to accomplish the established learning outcomes. Supporters of this method emphasize that the implementation of jigsaw can help learners build up their self-confidence. The latter is defined as a CT disposition [9].

All things considered, we identified all the CT skills proposed by Facione [9], while we did not trace any evidence regarding three certain kinds of dispositions: analyticity, systematicity and cognitive maturity. Analyticity is about using evidence to resolve problems. Systematicity is a kind of disposition that relates to an individual that can be organized in an inquiry, while the cognitive maturity associates with the identification that some situations have more than one plausible option [9]. It is expected that additional educational material in future implementations could promote these three dispositions. For example, in the water filter unit, we could add an alternative solution concerning the water purification, namely the integration of carbon nanotubes to the filter matrix [39]. We may demonstrate that the drawbacks of the nanopores water filter (e.g. reusability) lead scientists and engineers to consider alternative solutions, such as the carbon nanotube filter. We argue that this kind of activities could help PTs to develop or enhance their cognitive maturity, as described above.

We consider that the impact of the present study on science education community is twofold: firstly, it describes a methodology about how to determine specific CT skills and dispositions within educational materials such as lesson plans, learners' worksheets and posters through an intervention. In particular, we emphasize the significance of drive-in questions that provide crucial insights concerning this direction. Moreover, the impact of this study associates with the contextualization of the particular research in a modern scientific field which already has serious effects on our everyday life, namely nanotechnology. The promotion of CT skills and dispositions in combination with the salient features of the modern content is something that can hardly be traced in other similar efforts published until now.

Our future research aims at studying whether PTs' CT skills and dispositions were really fostered through this nanotechnology module. We are going to create an instrument that will assess the extent of CT skills' and dispositions' promotion. We plan to implement some already designed instruments, such as the California Critical Thinking Disposition Inventory (CCTDI) [40], the California Critical Thinking Skills Test [41] or self-rating forms [9]. These particular instruments contain several Likert style items for estimating whether certain CT skills and dispositions were promoted. We are thinking of using some of these items with some alterations, conformed with the features of the Nanotechnology module (abstractness of the nanoscale, myriads of applications, etc.).

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Promoting Critical Thinking Dispositions in Children and Adolescents Through Human-Robot Interaction with Socially Assistive Robots

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Abstract. The current paper describes a preliminary concept according to which robotic tutors are employed for promoting critical thinking dispositions in children and adolescents between the age of 10 and 18. Although critical thinking is among the most essential 21st-century skills, still is a challenging task for educators to achieve. However, robotic tutors motivate users and facilitate knowledge gains and behavioral changes due to their personalized behavior towards users' needs. Still, they have not been employed for promoting critical thinking. Here we present an experimental set-up according to which a robotic tutor introduces stimuli to the learner and engages in discussion resulting in the evidence-based inquiry. The robot employs questions, hints, and gestures through the discussion for the promotion of critical thinking dispositions. A holistic approach to critical thinking instruction is employed, yet without explicitly teaching critical thinking skills. Implications are discussed concerning the evaluation and measurement of critical thinking dispositions.

Keywords: Critical thinking · Critical thinking dispositions · Human-Robot Interaction · Socially Assistive Robots

1 Introduction

As the world has transformed from an industrial society to a knowledge-based society, the necessary skills for the workforce have evolved. These set of skills, described as the 21st-century skills, have been characterized as essential for education and future workforce in order for future citizens to function effectively in the society [1]. Particularly for school, 21st-century skills are essential due to the challenges the younger generation will encounter in the new global economy with the emergence of sophisticated Information and Technologies Communication (ICTs) [2]. Therefore, a need to shift from knowledge acquisition, which was important for the 20th-century education,

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to the development of skills and competencies has emerged [2]. Corresponding to this need, many academics and policymakers have suggested reforms in curricula and education standards aiming to include 21st-century skills in everyday teaching practices [3, 4]. Critical Thinking (CT) has been highlighted as one of the 21st-century skills and essential education goal for future citizens since it is a process aiming to produce reasonable and reflective decisions on what to believe or do [5]. In this way, CT allows individuals to make autonomous decisions and to question beliefs when these do not result in solid evidence [6, 7].

Although CT has been singled out as one of the most vital 21st-century skills [6], teaching for CT is not an easy task for teachers, instructors, or academics to achieve. First, teaching for CT is a challenging task, due to the disagreements on CT definitions and its complex nature. This results in another debate, namely whether CT is domain specific or domain general. In the first case, CT can be taught in domain-specific subject matters, while in the latter case CT can be generalized across domains and taught generically [8]. Moreover, such epistemological presuppositions have consequences on the strategies employed for CT instruction. Halpern [6] suggests the need for the explicit teaching of CT because there is little evidence suggesting that CT merely develops because of instruction in a discipline. Additionally, deliberate and repeated practice is required for CT to be transferred in different contexts [9]. Finally, CT is challenging to master through education and training because it is a higher-order-skill; built-up by lower-order thinking skills (e.g., ability to recall or understand information), which first need to be developed [10, 11]. Therefore, it is a challenge for educators to develop innovative interventions that will promote critical thinking skills in individuals. In the current paper, we argue that the development of a holistic approach that will integrate Socially Assistive Robots (SAR) as an integral part of the explicit instruction will be a useful tool for promoting CT in children and adolescents (i.e., between 10 and 18 years old).

SARs have been employed widely in the field of education due to their potential to improve teaching and learning [12]. Until recently, robotics have been employed more like a lab tool for educational activities that supports instruction of STEM-related subjects, as well as skills development related to the problem-solving and scientific inquiry. Nevertheless, with the advent of SAR, the role of the robots employed in education has slightly shifted from that of a tool to a more active peer or tutor [13]. Beyond the robot's capabilities of moving and acting autonomously, the robot's physical embodiment and the abilities to communicate and interact with users in a social manner (e.g., use speech and gestures to provide feedback) has proved to be beneficial for motivating and engaging users in Human-Robot Interaction (HRI) [14]. SAR's successes in motivating humans rely on the inherent human tendency to engage with lifelike social behavior, [15] as well as to their ability to persuade them in committing to a particular behavior or activity [16]. Literature findings suggest that manipulation of the robot's social cues (i.e., physical, psychological, language, social dynamics, and social roles) affect the robot's persuasiveness and therefore influence HRI [17]. Moreover, the responsiveness SAR exhibit towards humans' needs is inherent in the formation of emotional bonds [18]. Furthermore, research has shown that people behave more socially towards a robot with personalized behavior and can even alter their own behavior [19].

In particular, in this work-in progress-paper, we will present a preliminary idea of how the implementation of SAR could take place in educational context aiming at promoting CT in children and adolescents between the age of 10 and 18 years old.

2 Promoting Critical Thinking Through Education

2.1 Conceptualization of Critical Thinking

CT is a broad term with many interpretations and has been extensively discussed over the years considering different academic disciplines. In this study, we adopt the concept as grounded in a Delphi research study [20], covering various study areas and suggesting that both cognitive (i.e., Critical Thinking Skills-CTS) and affective aspects (i.e., Critical Thinking Dispositions-CTD) are essential for CT. According to the results of this study CT is defined as a process of purposeful, self-regulatory judgment, which results in two different procedures; (i) the interpretation, analysis, evaluation and inference, and (ii) the explanation of the evidential, conceptual, methodological or contextual considerations upon which the original judgment was based. Additionally, the definition deepens further, indicating the virtues or qualities that a critical thinker has such as inquisitiveness, concern to become or remain well informed, trust in the process of reasoning, open-mindedness, fair-mindedness in appraising reasoning, honesty in facing one's bias, stereotypes and prejudices, prudence in making judgments, willingness to reconsider one's judgments [20]. In addition, critical thinkers confront questions or problems with, clarity in stating questions or concerns, orderliness in working with complexity, diligence in seeking information, reasonableness in selecting and applying criteria, care in focusing at the issue at hand, persistence when difficulties are encountered and precision to the degree allowed by the subject under investigation [20]. Accordingly, six core cognitive skills are indicated when it comes to CT; (i) interpretation, (ii) analysis, (iii) inference, (iv) evaluation, (v) explanation and (vi) self-regulation.

Building on the findings of the Delphi study Facione stated that CTS alone are a necessary but not a sufficient condition for the development of CT. Therefore, it made explicit that a critical thinker displays certain dispositions, namely (i) truth-seeking, (ii) open-mindedness, (iii) analyticity, (iv) systematicity, (v) self-confidence, (vi) inquisitiveness, (vii) maturity of judgement, when involved in CT processes [21, 22]. Dispositions are considered as the consistent internal motivation to engage with problems and make decisions by thinking critically [23]. Truth-seeking is perceived as the eagerness to seek the best knowledge in a given context, being courageous about asking questions, objective and honest about pursuing the inquiry. The CTD of being open-minded is the process of being tolerant of divergent views and sensitive to personal bias. Analyticity is a CTD for applying reasoning and using the information to solve problems, anticipating potential conceptual or practical difficulties and be ready to intervene, when needed. Systematicity is the CTD where one organizes his thinking and actions in problem-solving and decision-making procedures and focuses on being diligent in the inquiry. Another CTD is self-confidence, which refers to trusting one's reasoned judgments and be inclined to lead others in problem-solving. Moreover, intellectual curiosity and desire to learn is considered the CTD of inquisitiveness. Finally, the maturity of judgment is related to particular context-based approaches and considerations of different opinions and ethical norms. Giancarlo, Blohm, and Urdan [24] highlight the importance of CTD indicating that it is insignificant to learn a CTS if when individuals are in need of that skill, they fail to exercise what they have learned. In addition, Ku and Ho [25] suggest that CTD affect thinking in various ways, such as providing to the individual the impetus to engage in deep thinking and reasoning processes. This is also justified by recent cognitive models of decision making (i.e., Dual Process Theory) proposing that the thinking process is facilitated by two systems of thinking (System 1 and System 2), which act in parallel while processing evidence during decision-making procedures [26, 27]. System 1 is more intuitive, reactive, and holistic and relies on heuristics. Thus, it is employed in situations that time is short and an immediate response is required. System 2 is useful for judgments related to unfamiliar situations, it allows the process of concepts, planning, considering options, review, revise and appreciate well-articulated evidence. If a person is critically disposed towards thinking and reasoning processes, namely values analytical thinking, truth-seeking, and open-mindedness, then it is more likely to activate the System 2 and engage in a more in-depth process of thinking which will result to better decision making [28]. Even in the case that the System 2 endorses an intuitive judgment, an individual who is critically disposed of will not be satisfied with the judgment until all possibilities have been checked and a satisfying solution has been reached by overriding the original intuitive judgment [29, 30].

2.2 Instruction for Critical Thinking

As presented earlier the on-going debate regarding the CT definition and its nature (i.e., domain-general or domain specific) has implications for the instruction of CT and its integration in the curricula. Ennis [5] suggested four different teaching approaches for CT, namely general, infusion, immersion and mixed approach. In the general approach, CT is taught separately from the content of a specific subject matter. In the case of infusion, instructors attempt to introduce CT in standard subject matters by making the general principles of CT explicit for students. Although immersion approach integrates CT in a specific subject matter, CT principles are not introduced directly to students. Finally, the mixed approach combines the general with either the infusion or the immersion approach. In their meta-analysis, Abrami et al. [31] identified the mixed approach as one with the most favorable effects for learners.

Apart from the approach, variations appear concerning the instruction methodologies of CT. Among the most common methods employed for CT are problem-based learning, inquiry teaching, computer-based instruction, serious games, concept mapping and higher-order questioning. Nevertheless, research in instruction for CT aiming to children and adolescents is more limited. For instance, collaborative group activities along with instructor guided questions and group debates have been utilized and proved to be more effective for secondary school students in promoting CTD than whole class instruction [32]. Similarly, primary education students' critical ability was significantly enhanced when engaged in collaborative-problem solving activities [33]. Moreover, a mixed approach towards CT employing inquiry-based teaching along with explicit instruction for enhancement of students' awareness of ideas, beliefs, and thinking processes proved beneficial for fostering students' CTD [34]. Finally, as the meta-analysis of [31] indicated the most effective techniques for CT enhancement are dialogue related type of strategies (e.g., questioning, peer discussion, debate) and authentic or anchored instruction (e.g., problem-solving techniques, simulations, case studies and role-plays).

Another issue related with CT instruction is the fact that the majority of studies emphasize more on the instruction of CTS underrating both the importance of CTD and the fact that CTS are developed after considerable practice and effort [6]. The undervaluing of CTD is a significant concern demonstrating that educators do not pay enough attention to their teaching and modeling in the class [35]. Also, Facione [21] argued that in the case that educational programs focus only on CTS and neglect the consistent internal motivation to use those skills (that is the dispositions), then education aiming at CT will fail. Acknowledging the need for instruction on CTD [36] proposed a four steps model. Firstly, the instructor should train learners so that they develop the dispositions to engage in CT, secondly teach them explicitly the critical thinking skills, thirdly design learning activities in ways that increase the probability of transferring these skills to other contexts and finally make metacognitive monitoring explicit. The literature review findings highlight that CTS and CTD cannot be distinguished during instruction. When one is motivated to think critically, he also engages in the CT process and therefore employs CTS. However, the issue is whether an instruction on CTS will be explicit or not so that the individual is aware of the skills he employs during thinking processes.

3 Socially Assistive Robots in Education

Socially Assistive Robots is a field where robots are employed aiming to provide motivational, engaging, social, personalized, and long-term support to people in different areas such as elderly care [e.g., 37] and (special) education [e.g., 13, 38]. The robot develops a close and effective, nonphysical, social interaction with the human to provide assistance [39] and support.

Despite the increasing number of initiatives exploring the use of SAR as agents in educational contexts, there are not yet any studies reporting results on promoting CT with SAR. Nevertheless, the latter are employed extensively for motivating behavior changes or engagement in learning activities. For instance, a robot that engages in verbal and non- verbal communication motivated primary school children to change their lifestyles and eating habits [40]. To illustrate further, elementary schoolchildren who interacted with a robotic partner, which they could teach handwriting were found to be more motivated to engage them in the activity. Also, metacognitive aspects were stimulated by the interaction with the robot as children had to reflect and consider why the robot failed to learn writing [41]. Moreover, when children played an interactive story-telling game with a physically embodied, affect-aware robot tutor in comparison to a tablet, children generated stronger engagement and enjoyment during the interaction [42]. The common denominator in all these cases responsible for increasing motivation in users and achieve behavior changes and learning gains were assumed the robot's social capabilities.

One of the social capabilities of the robot with particular interest for the current study is the personalization of the robotic tutor behavior towards the users' needs. Its importance is highlighted by the fact that it can lead to a motivated user who eventually achieves learning gains and behavioral changes. This can be interpreted by the Self-Determination Theory (SDT) proposed by Ryan and Deci [e.g., 43]. According to SDT, an individual becomes internally motivated to engage in a task when his basic psychological needs (i.e., the need for self-competence, need for autonomy, and need for relatedness) are satisfied. With a robot's personalized behavior, which can be achieved with various ways such as increase of the friendliness or social presence, the customization of the robot's appearance and personality, the task preferences or the feedback provided to the user [44, 45], this is more likely to be achieved. For instance, the need for self-competence could be facilitated in the case that the robot personalizes the level of a task's difficulty, according to the user's level of performance. In this case, the individual is more likely to feel competent enough to deal with a particular task that is not, more demanding than the person perceives. Latter on recent research findings will be presented to support this assertion.

Gordon and Breazeal [45] employed the continuous and efficient assessment of the student's skills, which led to a personalized behavior of the robot towards elementary school children. The robot was presented as a peer that wished to learn reading. Children who interacted with a personalized robotic tutor in comparison to random tutoring optimized their information gain and revealed substantial engagement in the task. In another study with primary school children, a humanoid robot- tablet game-child interaction was employed to challenge pupils' learning performance and increase their motivation. The robot adapted the level of assignments within the game to a child's performance. Results revealed that children were more motivated to be engaged with the robot that provided them with a personalized task in comparison to the robot that did not provide a similar behavior [46].

Hence higher order cognitive skills, such as self-regulation, can be observed more in primary school children when the robotic tutor adaptively scaffolds self-regulated behavior [47, 48]. This scaffolding took place through an open learner model, where pupils engaged in a geography task and were provided domain tutoring information by the robot, namely introduction to the task, its tools and performing of idle motions. Additionally, according to the children's answers, the robot engaged in verbal and nonverbal feedback (control case) as well as in feedback that scaffolded self-regulation. This feedback was initiated by different triggers related to the users' actions in the task (e.g., not mastering an activity, timeout, inappropriate tool selection). According to the authors, the robot by providing self-regulated feedback, facilitated pupils reflection on their current abilities, strengths, and weaknesses so that they could eventually re-organize their learning through the appropriate selection of tools or activities within the task.

4 Promoting Critical Thinking Dispositions with Socially Assistive Robots: A Proposal

The current study presents a preliminary concept on how CTD could be promoted through the employment of SAR, and it is part of an ongoing project (2016–2019) called STIMEY- Science, Technology, Innovation, Mathematics, Engineering for the Young, funded by the European program Horizon 2020 [http://promostimey.uca.es/]. With respect to instruction on CT we will employ Halpern's CT model, but since the emphasis is not on the CTS rather on the CTD, the first will not be explicitly taught as suggested in the model. In addition, the infusion approach as suggested by Ennis [5] will be employed along with evidence-based inquiry method.

A SAR will be developed within the context of the STIMEY project, which will operate through a detachable Android phone [49]. The robot will be personalized regarding appearance and personality since the user could modify it according to his/her preferences (e.g., change the colors, dress it appropriately, and choose a voice according to a specific gender). Also, personalized behavior will be achieved through feedback provided to the user as well as personalized responses according to user's progress in a task. Among other functions, the robotic tutor will motivate participants to employ CTD when engaged in inquiry-process through personalized responses and feedback.

4.1 The Experimental Set-Up

The robot will be positioned on user's table, opposite the user in order for it to be at a similar height to the learner. The robot will initially greet the user and will introduce a stimulus to initiate a discussion and engage the user in the evidence-based inquiry. This stimulus will be a short quote from an internet article, regarding a scientific phenomenon, e.g., "Seasonal changes happen because of the distance the earth has from the sun". The authors will develop the material and the selection of quotes so that they will depict learners' misconceptions on different scientific phenomena. In addition, misconceptions will vary depending on the child's age, since some of them can be surpassed during adolescence. After presenting the stimuli, the robot asks the user to consider it regarding its truthfulness. Figure 1. depicts a potential dialogue between the child and the robot regarding the original stimulus. With the first question, the CTD of truthfulness is triggered. Then the robot prompts the child to engage in an evidence-based inquiry. Here it is apparent that the user will be engaged in processes that involve CTS. Nevertheless, no direct instruction on CTS will be initiated. Additionally, the user will be able to use the smartphone embodied on the robot for the internet search. During this inquiry process, the robot will remain idle (e.g., smile, change colors).

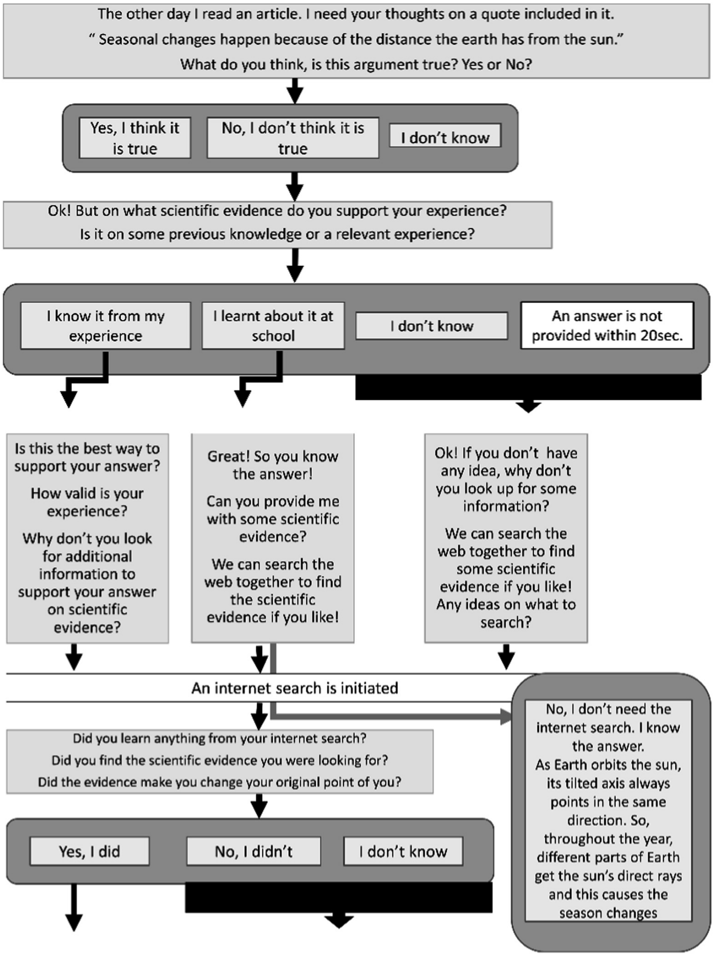

Fig. 1. The tree diagram depicting the interaction between the child and the robot; light grey is for the robot's responses, dark grey for the users' responses and white for triggers.

Additionally, if the user persists on looking for evidence, the robot will provide positive feedback encouraging him to continue. In the case that the search is irrelevant to the subject, the robot will ask the user to try alternative entries and stay more focused. Also, some robot's gestures and noises will be employed depending on the response (i.e., positive or sympathetic response). By the end of the interaction between the robot and the user, the first one will provide a reflection on different processes the child was involved in making explicit the CTD involved in each stage, e.g., "I think it really helped you that you sought for the truth of the original argument. Also, you found a lot of evidence that made your opinion more solid than before; you should do it more often!" To avoid repetition of the same questions concerning each disposition different set of phrases will be employed. Table 1 presents some indicative and alternative questions for the interaction.

Table 1. Robot responses related to CT dispositions

CT Dispositions	Robot response
Truth-seeking	- Is this argument true? - Did you question any of your beliefs? - Is this the best knowledge on which you can build your argument? - Did you find information on both sides of the argument? - Are there any consequences related to your argument?
Open-mindedness	- Did you respect different opinions on your argument? - Did you appreciate or laugh at others' arguments?
Analyticity	- Did you think the outcomes of your decisions? - Did you use evidence when tried to resolve the problem? - Did you think in advance any difficulties related to your argument?
Systematicity	- Did you organize your approach to solve an issue or problem? - Which steps did you follow to search for evidence? - Did you try to solve a problem without thinking in advance how to solve it?
Self-confidence	- Did you have confidence when you tried to solve a challenging problem? - Did you work on the problem or did you asked for help?
Inquisitiveness	- Did you learn something new? - Was this new information/evidence important for you? - Did you engage in an activity because it is useful for you?
Maturity of judgment	- Did you reconsider your argument according to other opinions? - Did you change your original belief according to the scientific evidence? - Were you willing to reconsider your argument at all?

Since CT cannot happen overnight, a longitudinal approach would be essential to investigate at least whether a long-term change in behavior is achieved. In that case, after a few sessions between the robot and the child, the interaction would differentiate minimizing the scaffold on behalf of the robot. For example, if a child systematically uses evidence to support an argument, the robot could differentiate the answer, and instead of asking the child to provide some evidence, it could suggest, "Usually you judge a statement according to scientific evidence. I hope you have found evidence for this …" Gradually the robot instead of making questions, it would ask the user to describe the procedures he is involved in while evaluating a statement (e.g., What is your first step in evaluating an argument?). Finally, if the user mastered the activity, a congratulation response would be triggered while some hints could be provided in the case that the user did not engage appropriately with CTD.

5 Concluding Remarks

We have presented a preliminary concept on how SAR could promote CTD through an introduction of stimuli that initiate an evidence-based inquiry for children and adolescents. The robotic tutor will motivate participants in employing CTD through personalized responses and feedback.

Robotic tutors are chosen in the current study to address the issue of individualized support that most schools lack (i.e., primary and secondary level) [50]. In addition, they are employed because they can support skills development and long-term behavior change [14]. Moreover, research findings suggest that robotic tutors are effective for increasing users' learning outcomes and engagement [46]. Still, although short-term studies (e.g., a single session) are usual, long-term explorations (e.g., over weeks or months) are relatively rare [51]. Future work will implement the current concept in a longitudinal study, where students and adolescents between the age of 10 and 18 will interact with the robot in 8 sessions, one per week over a period of 2 months. Each session will be limited up to 20 min of interaction. Additionally, pre, post, and delayed post measurements will be conducted to evaluate the effects of the intervention.

Still, challenges related to the evaluation and measurement of CT are evident. Reliability and validity issues prevent the widespread use of different scales, inventories, and standardized tests developed for measuring CTS and CTD [52]. Another barrier in CT measurement is its nature consisting of both skills and dispositions. This means that an individual who is disposed to think critically or who has developed CTS only is not a priori, a critical thinker. Therefore, here we propose a qualitative measurement of CTD with a self-evaluation task. Learners will be engaged in the process of describing the CTD they are engaged in during the activity. This measurement presupposes that learners at least know which are the CTD. Additionally, a similar task like the one of the experimental condition with a different context will be provided to learners. In this way, transferability of motivation to engage in CT-namely CTD will be evaluated.

Finally, development of CT is not an easy process to achieve. A systematic approach addressing both CTS and CTD is required. Thus, instruction for CT should be initiated from a small age and be targeted as a lifetime goal. Although the current concept lacks the explicit instruction of CTS, it does not omit CTS. Hence, by employing the advantages of robotic tutors as highlighted in the research field, we aim at a long-term behavior change.

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Teachers' Critical Thinking Dispositions Through Their Engagement in Action Research Projects: An Example of Best Practice

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Abstract. Critical Thinking is considered an essential component of education given its potential to enhance students' development at an academic, value-related and moral level. Teachers' critical thinking dispositions may be utilized in school settings in order for them to design teaching practices that are focused on the cultivation of students' critical reasoning. The current qualitative study aims to explore teachers' Critical Thinking dispositions as they emerged through an action research project carried out in Macedonia, Greece involving semi-structured interviews and a focus group. Three major subject areas were explored including resilience, peer mediation and citizenship education. Ten teachers of primary education and three teachers of secondary education (Lyceum) participated in the study. Qualitative data findings have suggested that teachers exhibit certain Critical Thinking dispositions which will inform teaching interventions to be designed and applied during this specific project.

Keywords: Critical Thinking · Resilience · Peer mediation · Citizenship education · Action research

1 Introduction

Today's world is characterised by ongoing change at socio-economic, scientific, technological, political and cultural levels. In order for students to better cope with the instability resulting from a dynamic and fluid environment, they require enhanced skills in developing positive self-esteem, inner security, harmonious communication and awareness of their rights and obligations. On the other hand, schools usually prioritize academic performance and strive for the development of cognitive skills –mainly of linguistic and logical-mathematical intelligence– while underestimating the future need for skills with moral, emotional and communicative dimensions. Nevertheless, apart from knowledge related to various subject matters, the mission of school is to provide value education for learners, thus contributing to their moral and democratic education. This attainment is aligned with the so-called 'double assignment of schools' [1, 2, pp. 154–156], which entails that 'teachers need to teach not only the subject

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matter itself; they need to teach in a way that complies with a set of overarching value-related goals as well' [2, p. 155]. Among these values, moral personality as well as responsible and democratic attitude to life is of major importance both outside and inside school settings.

Students starting from primary education until Lyceum should have an opportunity to develop their identity and learn how to 'get involved' in society [3]; to give meaning to life and develop a sense of agency; to consider conflicting values, participate in value-oriented discourses and be involved in establishing and even altering normative moral rule systems; to examine their perceptions, beliefs, attitudes and values concerning the problems they are opposed to; and to contribute to evolving democracy and sustainability in a global world. These compelling necessities aim at the emancipation of the new generation, the acquaintance of valid knowledge and the preparation for life.

The challenge of responding to these necessities presupposes, among other things, the development of higher-order thinking skills on the part of future citizens. Deriving from Aristotle' s philosophy and examined within a variety of fields, the ability of Critical Thinking (CT) has been continuously expanded to encompass more and more areas of thought in our times.

2 Background

Although CT is unfairly portrayed as cold and unemotional, it often entails the skill to "see" issues from the perspective of other individuals, thus including empathy, value setting, communication and understanding as a way to alter emotional responses [4]. In this regard, the Delphi Report –the culmination of work by experts from the American Philosophical Association (APA)– argues that educating strong critical thinkers requires a combination of "developing CT skills with nurturing those dispositions which consistently yield useful insights and which are the basis of a rational and democratic society" [5, p. 3]. CT dispositions are represented as equally significant to the ability to perform CT skills, whilst the majority of research in CT field focuses only on skills [6]. Furthermore, disposition towards CT may be explored when teaching and using CT skills [7].

In the APA Delphi Report seven dispositions are conceptualized: inquisitiveness, open-mindedness, systematicity, analyticity, truth-seeking, CT self-confidence and maturity. Inquisitiveness refers to one's will to learn even when application of knowledge is not readily seen. Open-mindedness correlates with tolerance to divergent views and concern over the possibility of personal bias while systematicity with organization as well as attentive and persistent inquiry. Analyticity is associated with the importance of reasoning and the use of evidence in problem solving, by being aware of the difficulties while simultaneously recognizing the need to intervene. Truth seeking concerns willingness to search for the best knowledge, courage when asking questions and honesty in inquiry. CT self-confidence represents one's trust to their reasoned judgments and inclination to rationally lead others to problem resolution. Finally, maturity can be attributed as one's awareness of problematic situations in decision making and problem solving, the possibility of more than one option and the cognizance that judgments should sometimes be made on bases that exclude certainty [7, p. 4].

When CT dispositions are related to cognitive developmental moral psychology, they can create a morally educative social climate within the school context. This dimension focuses on the development of moral reasoning and action that is philosophically autonomous, far from techno-bureaucratic strategies of problem solving. It also encourages students to democratically express personal opinions, supportive or divergent viewpoints, as well as to share and debate points of reasoning challenged by a difficult-to-resolve conflict [8].

Recognizing the need for CT applies not only to students but also to teachers, especially when they deliver initiatives which make the complexities of their profession visible and build their capacity around an enhanced understanding of their own teaching. It is a teachers' responsibility that students develop their willingness to engage in the effortful work of developing and applying CT skills. This entails the capacity on the part of students to recognize which skills are likely to be useful, to have at their disposal a repertoire of skills to select amongst, as well as self-knowledge to monitor any progress on the task. Students should be able to develop capacity for sound understanding and judgment through deliberation. Teachers should be competent to sharpen, as Aristotle maintains, both understanding and practical wisdom [9, pp. 62–63].

While discussing topics relevant to critical reasoning in classroom, it is considered conducive for teachers to encourage a disposition for investigation into the topic at hand, using critical questioning to elicit assumptions rather than information, and also to promote arguments, evidence, counter-evidence and other components of CT; in a word, to make the connection between developmental epistemology and critical thinking [10, pp. 101–121]. Furthermore, in addition to teachers being specific, working deductively and being conversational, they could use techniques for imagining alternatives, such as brainstorming, envisioning futures, developing scenarios, inventing futures and esthetic triggers (poetry, fantasy, art, songwriting or drama) which would contribute to the objective of teaching for CT [11].

The endeavor, and more importantly the awareness of the endeavor, to promote students' higher order thinking development is an element of teachers' professionalism which can be described through Schön' s term "reflection-in-action" [12, p. 62]. This orientation demands highly professional knowledge and performance on the part of the teacher, which is called 'the epistemology of practice' [12, pp. xi, 33]. This concept includes 'school knowledge', as well as a kind of artistry that characterizes teachers in their everyday work, while they are attaining reflective and critical processes.

3 Description of the Project

Based on the above rationale, a collaborative research project in primary and secondary schools entitled *"Development of resilience, peer counseling and citizenship awareness among students. The implementation of an intervention project"* is currently in progress at the University of Western Macedonia, Greece[1]. The project aims to offer new perspectives in exploring the school curriculum and enriching educational objectives so that concepts related to students' moral development and democratic

[1] The project has been assessed and funded by the program *Researchers Support with emphasis on New Researchers* of the Greek Ministry of Education, Research and Religious Affairs and the European Social Fund (2018–2019).

pedagogy can be integrated. The expected result is evidence-based valid scientific knowledge and the potential for constructing substantial, innovative and scientifically valid procedural knowledge on part of teachers.

Based on the principles of participatory teaching methods, the project involves students and teachers under the guidance of three researchers who are also teachers in three inter-related components: (a) personal empowerment of pupils focused on their resilience (RSL), (b) peer counseling with emphasis on peer mediation (PMD) and (c) citizenship education (CZE). More specifically, teachers cooperating with the researchers will be encouraged to design and apply cross-curricular activities through a series of teaching interventions for their students to become aware and gradually immerse in the concepts of RSL, PMD and CZE. Regarding PMD students' parents will also participate in the study as they will be asked to trace potential behavioral change in their children after the completion of the project, thus contributing to its assessment. At the end of the project, teachers are expected to be able to apply effective practices for their students; students are expected to potentially be empowered to create personal positive attitudes and friendly bonds under the construction of a secure framework for the more vulnerable ones (regarding RSL and PMD, respectively) as well as to develop socio-cultural and political ethos (regarding CZE).

The three subject areas of the project seem to be interrelated in the limelight of values and democratic education, as they focus on students' self-knowledge and empowerment (RSL), their harmonious social interaction with peers and groups (PMD) and simultaneously their future role as active citizens through earnest contribution to their civic community (CZE). Values may stand as references in decision making and students' beliefs while they are related to their identity and character [13]. That way, values education may be encouraging to the development of CT for students, while simultaneously the existence of CT dispositions and skills in teachers can safeguard the continuation of this project with coherence. This concept recapitulates the rationale of the project as it is depicted schematically in Fig. 1.

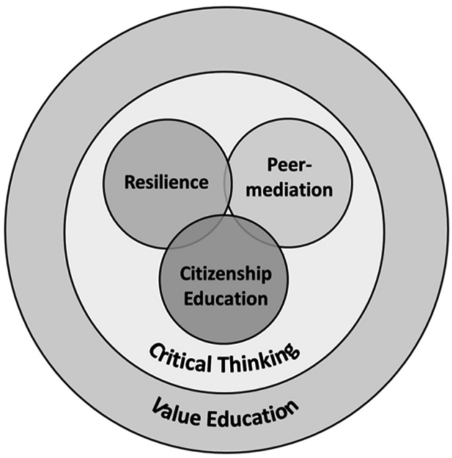

Fig. 1. The rationale of the project

In detail, regarding the three subject areas of the project, RSL correlates with human ability to deal with and hopefully overcome any perilous life conditions [14]. RSL can be cultivated through various activities in school settings and contribute to the promotion of academic performance, moral empowerment, empathy and emotional intelligence of the students while utilizing intrinsic motivation [15]. For PMD, it is considered that through conflict resolution education, with peer mediation being a major element of it, students can be taught to turn their conflicts into new ideas and respect their peers' different perspectives. This way, violence in school settings tends to be significantly reduced [16] and school climate potentially becomes more creative [17]. Concerning CZE, the concept of cultivating students' citizenship is not only narrowly restricted to the understanding of political institutions and democratic processes but rather expands to moral and emotional development through active, social, cooperative and critical learning. Methods promoting students' participation in their community, peaceful and cross-cultural education as well as critical literacy especially towards media are of paramount importance in CZE field [18].

During the design of the project, special emphasis was placed on applied research relevant to education practice, whereas research methodology was dictated by the theoretical principles of action research [19]. Researchers cooperated with the school principals and teachers of each school and since they held the role of "critical friends", they offered advice for the optimum implementation of the project, stimulated teachers for further reflection and consulted them on teaching and activities design [20]. The project was initiated by tracing the existing needs in order for teachers and researchers to later develop a series of teaching interventions in classes of 8 primary schools of Western Macedonia for RSL and PMD, and of 3 Lyceums of Thessaloniki (Central Macedonia) for CZE.

The whole process was expected to have a positive impact on teachers' professional development, evoking them to build a "know how" in implementing school practices for the improvement of students' moral courage, the development of their skills in negotiating conflicts, and the enhancement of their citizenship awareness. The teachers' engagement in action research efforts as members of a teaching community was expected to strengthen their competencies as decision makers and self-regulated professionals and enhance their reflection and their metacognition [21, 22]. In other words, through teachers participation in research process their professional role will be developed [23] since they will be asked to construct new teaching processes and therefore approach already acquired pedagogical theories afresh [24]. That way, teachers are expected to thoroughly understand their capabilities and/or limits, make decisions and contribute to the development of the teaching process in a new direction while combining reflection and self-assessment, being continuously supported by the researchers [25].

The purpose of this paper is to examine the extent to which teachers participating in the project were ready to hold an active and participatory role cooperating with the researchers and applying new teaching processes in their classroom settings, thus responding to this particular project objective. This readiness is explored in the light of teachers' CT dispositions through their answers regarding the three components of the project, thereby determining both their willingness and ability to hold the role of "educational agent" and promote not only knowledge but also values in school settings.

The evidence drawn from the study may be an invaluable tool in designing flexible teaching interventions and may also hopefully stand as a validity claim for the successful continuation of the project. Therefore, the paper seeks to address the following questions:

- To what extent do teachers' CT dispositions include characteristics that can contribute to the promotion of students' moral, emotional and social empowerment?
- Which particular aspects of teachers' CT dispositions can be correlated with their ability to support resilience, peer mediation and citizenship education among their students?
- Which educational initiatives can be delivered through this project, so that teachers' CT dispositions can be utilized in the direction of the attainments of the project?

4 Methodology

The current qualitative study concerns the initial phase of the aforementioned project and focuses only on the teachers participating in it. For the optimum implementation of the project, the researchers carried out interviews with the teachers concerning their readiness to support students' RSL and CZE, as well as a focus group for teachers of PMD. The criteria for the teachers' participation in the project were based on the identification of students' profiles of low resilience skills, uncontrolled conflicts among students in their schools and teachers' willingness to apply innovative educational strategies in classes of diverse student populations in order to promote democratic citizenship education.

4.1 Participants

Thirteen teachers aged 39–55 (8 women and 5 men) with a teaching experience ranging between 10 and 28 years, participated in the study. Among these, ten teachers work in the primary school and three of them in Lyceum, coming from three different types of senior high school (general, intercultural and experimental senior high school). One of them teaches Greek Language and Literature and the other two Civic Education. For the subject areas of RSL and PMD, the participants were students of fourth, fifth and sixth grade (three last classes of primary school), while for CZE, they attend the 1st class of Lyceum. The reason for this variation lies in the fact that for RSL and PMD, emphasis was put on self and social learning, hence the selection of younger student participants, since emotional development is in the limelight at this age. For CZE, political learning was prioritized [18, p. 8]; thus adolescent students were selected, since they were at the point of entering society as adults with rights and obligations. It is worth mentioning that the student participants of RSL and PMD were at the early stages of preadolescence and those of CZE at the culmination of adolescence. The participants of the project are described in Table 1.

Table 1. The project participants

Participants					
The axes of the project	Teachers' number	Teachers' age	Teachers' gender	Teachers' working experience	Students' age
RSL	5	47–55	4 women 1 man	15–27	9–12
PMD	5	48–55	3 women 2 men	25–28	9–11
CZE	3	39–55	1 woman 2 men	10–25	15–16

4.2 Data Collection

A set of different research tools for each area of research interest were designed and implemented with teacher participants: (a) a semi-structured interview for RSL and CZE and (b) a focus group for PMD. The questions of both the semi-structures interviews and the focus group were constructed in the light of modern qualitative methods and after thorough research of current literature. They were all carried out by the three researchers independently in school settings at the first stage of the project, that is after the teachers agreed with their participation in it. For RSL, the semi-structured interviews lasted for 40–50 min and the teachers were asked to answer 9 questions regarding their routine in primary school (e.g. *"Have you noticed any changes in your students over the last years? Can you describe the reasons for these changes?*"), 11 questions for their routine in classroom settings (e.g. *"In what way do you believe that students' academic performance is influenced because their families are experiencing problems due to the financial crisis?"*), 12 questions referring to their professional profile (e.g. *"Do you ever take the initiative to help in problems caused in your classroom due to the financial crisis? What do you do exactly?"*) and 15 questions for their personal profile (e.g. *"Describe your general concern because of the financial crisis at a personal level"*). Regarding PMD, the focus group lasted for approximately 1 h and the teachers were asked to discuss on 7 questions relating to students' conflicts, the existing reasons for them, the frequency, the potential gender differences in conflicting situations and their own intervention (e.g. *"What are the most common reasons for students' conflicts?", "How do you tackle conflicts between students in school settings?"*); 3 questions for the conflicts consequences (e.g. *"Do you believe that conflicts may have consequences for students' academic performance? Why?*") and 2 questions about parental intervention (e.g. *"What are the possible results of parental intervention in students' conflicts? Why?*"). For CZE, the semi-structured interviews lasted for 30-40 min and included 10 questions focusing on teachers' perceptions of the role of school and themselves (e.g. *"In your opinion, what are the targets that school and teachers should serve? Do you believe that these targets are accomplished? If yes, how? If no, why?"*) as well as the development of democracy and citizenship education in school settings (e.g. *"In your opinion how do you define a* *democratic citizen? How important is the role of school in the development of citizenship?"*).

Qualitative research methodology was selected given that in-depth analysis and interpretation of the teachers' perceptions were considered as essential for the implementation of the project. It was assumed that through semi-structured interviews, the researchers could be actively engaged in critically analyzing the teachers' ideas [26] and perceptions, literally learning from their experience and thoroughly delving into their classrooms' culture. The utilisation of focus group settings enabled interaction among participants and encouraged them to ask questions and reflect on each other's answers. This allowed the researchers the opportunity to collect qualitative data that might otherwise have not been taken into consideration regarding teachers' perceptions [27]. A combination of these two qualitative methods was selected since it was considered as a productive approach to the detailed description of teachers' dispositions aiming at enhanced understanding and data richness [28].

4.3 Data Assessment

Collected data were assessed with the method of content analysis, on the basis of Facione' s research tool for CT dispositions [5], which recognizes seven dispositions (see Background). The researchers assessed the teachers' answers in the light of their CT dispositions, attempting to extract elements that exhibit teachers' dispositions while they were commenting on the fields related to the project. Teachers' answers were analyzed qualitatively. Seven categories were used, one for every disposition. Before the final coding, two trained research assistants classified 20% of participants' answers into the seven categories. Cohen's kappa was run to determine the level of agreement between the two researchers. The inter-rater agreement was excellent ($\kappa = .91$ (95% CI, .89 to 0.93), $p < .001$), and was increased to 100% after discussion with the authors.

5 Results

After the qualitative analysis of the data, teachers seem to exhibit a number of CT dispositions while dealing with school routine, conflicts and their perspectives of citizenship education.

Eleven out of thirteen teachers reveal their truth-seeking disposition by being willing to seek the best knowledge in terms of teaching methodology and behavior reflecting on their actions (RSL). They also appear to be willing to seek the necessary evidence as far as it concerns the reasons for students' conflicts (PMD). When they are being asked about school and teachers' role in modern world, they seem to be aware of their significant role in developing future citizens and societies (CZE).

Open-mindedness and tolerance to divergent views is exhibited by twelve out of thirteen teachers. For example they seem to comprehend students' negative attitude to learning as a result of their experiencing problematic situations (RSL); understand the diversity of opinions as a main reason for conflicts and disagreements (PMD) and anticipate a school open to the world with open-minded teachers, accepting diversity, cultivating art and "developing students' moral education" (CZE).

They all seem to be analytically disposed, using application of the reasoning and evidence to resolve problems or potentially anticipating conceptual or practical difficulties while being ready to intervene. Specifically, they recognize that cooperation between teachers positively affects students (RSL). They continuously evaluate a conflict's extent and they are ready to intervene when needed, recognizing that conflicts may oblige them to reschedule their planning (PMD). They also work with their students on political articles, trying to identify their application in real-life conditions and applying reasoning to resolve problems (CZE).

They all seem to be systematic. They are trying to be organized, orderly and focused when they orchestrate actions with the available materials considering the restricted financial resources (RSL). They thoroughly collect information from the disputants regarding their conflict and try to apply a common set of rules in the direction of conflict resolution (PMD). They are presented with precise ideas on the development of CT in school settings claiming that experiential learning can contribute to this aim (CZE).

Most teachers trust their own reasoned judgments regarding overcoming financial difficulties that negatively affect their own and their students' psychology while trying to invest and ameliorate their students' mood (RSL). They also hold a responsible role leading their students to conflict resolution by activating various practices of problem solving (PMD). The concept of responsibility towards students also arises in terms of their preparation for the future (CZE). These elements seem to highlight their disposition of self-confidence revealed by eleven out of thirteen teachers.

All teachers exhibit the disposition of inquisitiveness as they are willing to learn, to be further trained in new learning methods and tools, as well as to be specialized (both at a personal and cooperative level) utilizing scientific guidance (RSL and CZE). They are also eager to learn and be supported by the anti-bullying programs their schools participate in (PMD).

All teachers' cognitive maturity is exhibited as they approach problems and make decisions recognizing the existing difficulties such as mandatorily extensive teaching material and students' problematic behavior even though they admit to making mistakes (RSL). According to their opinion, these mistakes are due to limited teaching time while they are trying to act in their students' best interest (RSL). Teachers seem to approach conflicts in an explanatory way, presenting and highlighting factors such as parental intervention that may inhibit their own work (PMD). Finally, they exhibit cognitive maturity through approaches based on concrete contexts, mentioning that students should also participate in school operation for them to delve into the concept of democracy (CZE). Teachers' dispositions with explanatory quotes are presented in Table 2.

Table 2. Teachers' CT dispositions

Disposition	Quotations/Codes
1. Truth seeking	"How many times do I leave school and reflect", "Did I do this well?" or "Didn't I do the other thing well?", "How could I do better?", "Didn't I behave well?" (RSLT5_24/11/2016)
	"Something else may be hidden and we have to look into it" (PMDT4_29/9/2017)
	"It is likely to achieve these goals to some extent, but fragmentarily and not as an institutional shell" (CZET3_30/7/2017)
2. Open-mindedness	"When parents are sad, or they (the students) face difficulties, can they be willing to learn?" (RSLT3_24/11/2016)
	"And I think that where there are people and different opinions and some try to impose their point of view to others… conflicts are expected" (PMDT3_29/9/2017)
	"I believe that teachers should be open-minded regardless their age" (CZE1_28/6/2017)
3. Analyticity	"When there is cooperation between us (the teachers), the children themselves learn to cooperate, otherwise the opposite happens" (RSLT3_24/11/2016)
	"Sometimes you start your day differently and this (a conflict) changes your plans and your programming" (PMDT4_29/9/2017)
	"I read a piece of news in classroom and students start decoding it and learning this kind of language" (CZET2_27/7/2017)
4. Systematicity	"I was very thrifty with the materials they had in their bag and with what they had to buy… too. I did not have a list…very few things. I adapt my lesson to my students' needs" (RSLT5_24/11/2016)
	"We usually call both parties (of a conflict) and we listen to both parties" (PMDT3_29/9/2017)
	"I would put much more project-based teaching methods that would potentially replace the typical lesson with the various school subjects with mainly experiential methods, art in the foreground… all these" (CZET1_28/6/2017)
5. Self-confidence	"I believe we will be able to cope, because I believe that people are very strong and can fight… we have faced difficulties over the last years but we will overcome them. We will surely overcome them" (RSLT2_18/5/2016)
	"I believe that tackling with problems in the classroom is what teachers are there for…" (PMDT3_29/9/2017)
	"They have a huge responsibility for tomorrow's citizens … and tomorrow's societies. So their role should be particularly well taken care of" (CZET1_28/6/2017)
6. Inquisitiveness	"Some teachers are not appropriately trained … further training, yes" (RSLT2_18/5/2016)
	"We, the teachers, will probably have to be further educated in practices that stimulate students' interest" (CZET2_27/7/2017)

(*continued*)

Table 2. (*continued*)

Disposition	Quotations/Codes
	"These programs about bullying have really helped us face some things, both us and the students" (PMDT2_29/9/2017)
7. Cognitive maturity	"I think that children are used to having everything they want, are not used to 'no' as an answer, they do not follow rules at home, so it is very difficult for them to keep the rules at school" (RSLT2_18/5/2016)
	"Dealing with time is a really pressing issue … and this is the reason why we behave in a certain way, it is because we have to…" (RSLT5_24/11/2016)
	"We need parents' cooperation; they love their children but they should also trust teachers and not underestimate them" (PMDT3_29/9/2017)
	"Students should be responsible for the operation of the school, they have to fully understand what democracy means" (CZET3_30/7/2017)

6 Discussion

Based on the evidence of the current qualitative study, it is possible to conclude that teachers exhibited dispositions that may significantly contribute to their students' moral, emotional and social development – a fact that is evidently conducive to school's double assignment. Teachers' dispositions reveal their readiness to adopt a responsible role in school settings and actively participate in this particular project. It is assumed that they may contribute to the effective implementation of the project, thus setting the stage for the enhancement of students' skills in terms of socialization and school performance. More specifically, their dispositions that showcase approaches to life and living in general [5] can be instilled into teaching processes facilitating self-confidence, positive relationships and citizenship awareness of students. Moreover, teachers' CT dispositions will be potentially extended beyond the limits of classroom leading students to the cultivation of global sensitivity [29]. On the other hand, having fortified their inner selves, students are expected to be capable of virtually experiencing democracy. This process may potentially equip them with mechanisms for moral growth and development through adulthood and lead to the acquisition of successful problem-solving and decision-making techniques that apply to a variety of life situations in the future.

Every aspect of teachers' CT dispositions can be correlated with their ability to support students' resilience, peer mediation and citizenship education. More specifically for RSL, teachers' CT dispositions correlate with elements of resilience, by being role models for their students, so that they can dynamically foster resilience development in the classroom settings [18, 30]. Teachers appeared to demonstrate highly organised qualities, to strive for life-long learning and to recognize the teaching processes that lead to personality development of students. Through their effort, students' self-confidence, social skills and readiness to challenge life difficulties may be promoted. Teachers may provide their students with academically effective agency, self-determination and self-control. Regarding social interaction and classroom atmosphere, positive relationships between teachers, students and their families may also successfully promote resilience [31].

As for the issue of PMD, teachers exhibiting CT dispositions may courageously hold a responsible role in understanding the causes of students' conflict. Simultaneously they may give their students the opportunity to be flexible, work out solutions, become experienced in problem solving and alleviate disagreements. Even when parental intervention is possibly obstructive towards their work and the school curriculum does not provide them with the essentials for conflict resolution education, teachers with such dispositions can diligently support their students to the best of their knowledge, in order to protect a favourable school climate and safeguard values such as respect and the ideal of cooperation in human relationships.

As far as student CZE is concerned, teachers' CT dispositions are expected to contribute to their students' developing democratic personalities. In any other case, teachers would have been restricted to their traditional role and cognitive goals, contradicting the principles and practices of democratic education. Thus, every CT disposition may be required for teachers' empowerment so that they can integrate theory into practice through reflective processes that lead to their emancipation and autonomy [32]. In this way, teachers are expected to be capable of overcoming existing difficulties and instilling their CT spirit in teaching processes for democracy and citizenship to safeguard their students and school's best interest for active, social, collaborative and critical learning. Such teachers can seek new methods for practical, ethical, socially oriented, responsible self-management of pupils and their participation in the society they belong to. At the same time, they can contribute to the demand for peace education and moral culture, for intercultural and environmental education, as well as critical literacy, especially with regard to mass media influences [18]. A holistic approach to human thought and behavior indicates that all of the above areas of interest are aspects of democracy education and citizenship. The establishment of such a framework for all students by the school promotes their moral development in the sense of moral reasoning and acting in a philosophically autonomous way [5, 33]; in this sense, it is anthropocentric, sustainable, ethical and optimistic for the future.

As suggested in the findings of this project, teachers' dispositions may play a significant role in school settings provided that educational material and strategies are developed to support the promotion and cultivation of these dispositions bilaterally; for teachers to apply these dispositions during teaching processes and for students to develop them. The cultivation of these dispositions is important to assure the utilization of CT skills even outside the process of formal education [5]. Taking this into account, initiatives should be taken so that students can be taught to respect and understand different opinions, thoroughly search for facts, use the power of reasoning and reflect on various situations. For this purpose, school should provide the foundation for entering a society that embraces new ideas whilst creating subject knowledge in different scientific fields. Teachers' dispositions may be assessed and later transformed into curricula aiming at the promotion of team work, problem-solving and/or decision-making techniques and moral dilemmas. This way, students may be encouraged to develop confidence in their CT skills while cultivating them, actualizing the double assignment of school as this is delineated in the introduction of the paper.

7 Research Limitations

Although this specific study has achieved its aims, there were limitations given its scope. Firstly the study was conducted only on a small number of participants. Therefore to generalize the results across a broader context, a larger number of participants would need to be involved. Additionally, even though teachers' CT dispositions reveal their readiness for action and eager participation in the project, there are no conclusive results from the teaching interventions, as yet. Consequently, the data of the study cannot be correlated with the results of the whole project at this time.

8 Suggestions for Further Research

The results of the current study may be capitalized when designing further research relevant to CT dispositions and skills in the field of education. Teachers who are familiarized with the idea of thinking critically and who apply CT skills in classroom settings can be inspired to promote and adapt a school curriculum with a new orientation. CT may be instilled in every school subject through cross-curricular practices ("infusion approach") [34, p. 1106] that will recede from behaviouristic patterns. Therefore, further research may possibly examine the ways that CT skills and dispositions can be taught to teachers through life-long learning, so that they can apply them in the teaching processes. Additionally, further questions can be posed regarding school curriculum, educational consultants and even the role of the Ministry of Education towards the empowerment of teachers' CT in school through their collaboration and engagement in action research projects.

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Enhancing College Students' Critical Thinking Skills in Cooperative Groups

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Abstract. This study examines the effects of cooperative learning interventions on college students' critical thinking (CT) development. It presents the results of an investigation in which 19 students were assigned to work in a cooperative learning (experimental group) context, and 22 other students (control group) followed a lecture-based learning process. The development of the students' critical thinking skills was subsequently assessed with a pre- and post-test. The results showed greater improvements in critical thinking skills among the students of the intervention group suggesting clearly that the effects of cooperative learning are very positive.

Keywords: Critical thinking · Cooperative learning · Lecture-based learning

1 Introduction

Educators, professors, and researchers alike believe that the development of critical thinking skills is essential for students because of their academic and real-world applications [1, 2]. Critical thinking generally leads to well-informed, more reasoned decision making processes [3] and is considered vital to the success of a democratic society [4]. Without critical thinking, society members are less equipped to engage in public discourse and participate in active citizenship. Critical thinking, a component of higher-order thinking [5] is a highly required educational skill that combines argument analysis problem solving and decision-making [6–11]. It is generally described as an individual's ability to evaluate and analyze arguments to determine which ones have merit and which not [7, 12]. It includes the capacity for interpretation, analysis, evaluation, inference, explanation and self-regulation [13]. Despite critical thinking importance, if significant percentages of college students successfully complete requirements for graduation, they do not progress, as expected, in the development of

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their critical thinking skills [14, 15]. In that sense, it is necessary to examine how these skills can be promoted in the classroom [16] along their academic path.

One of strategies that has been pointed out as being effective to develop critical thinking is cooperative learning [2, 17–20]. Cooperative learning refers to students working together in an attempt to create knowledge and achieve shared learning goals [21, 22]. Previous work [23–25], offered a persuasive argument on why cooperative learning might positively influence students' cognitive development. First, it is believed that cognitive disequilibrium occurs as a result of the sociocognitive conflict that arises when individuals work together to achieve shared educational goals. Next, it is thought that the construction of new knowledge is often built on students' experiences when working with others in the cooperative learning process. As some authors argued [25], "cooperative learners cognitively rehearse and restructure information to retain it in memory and incorporate it into existing cognitive structures" (p. 120). This process is thought to occur when members of the group are exposed to the intellectual diversity of others in the group as they are confronted with innovative or different ways of looking at familiar problems [26]. Viewed from Piaget's perspective, instructors can be seen as facilitators of students' learning, rather than people who simply deliver content to students. This orientation allows for social interaction, cognitive conflicts, and therefore disequilibrium in students, which in turn spurs intellectual development and cognitive growth [27].

In short, cooperative learning approaches may lead to the development of the need for cognition, by helping students enjoy the process of learning together and may be more efficient to develop critical thinking than through a lecture or individual educational approaches [28–30]. Although most of the research on outcomes associated with cooperative learning has been conducted at the primary and secondary levels of education [31], there is an emerging literature on this issue at the higher education level as well [21, 32, 33]. In higher education, cooperative learning has been identified as a promising and effective instructional approach [34]. However, there is little evidence drawn from experimental research supporting that cooperative learning influences positively college students' cognitive development in general and critical-thinking skills in particular [35–37].

This gap in the literature is rather surprising given that critical thinking is cited by employers and college professors alike as one of the most important learning outcomes among college students [38, 39]. This paper addresses this gap and contributes to demonstrate how using cooperative learning strategies may assist students in developing critical thinking skills. To the best of our knowledge few research studies have focused on the link between the pedagogic cooperative approach and the enhancement of college students' critical thinking skills. The present study was therefore carried out to contribute to this reflection and address the following research question: is there any statistically significant difference between the development of college students' critical thinking skills using a cooperative learning approach or using a traditional lecture-based approach?

2 Method

2.1 Design

To answer to the question above, a nonequivalent control group pretest–posttest design was used in this quasi-experimental study. The research compared the effects of instruction on critical thinking skills using cooperative learning strategies versus traditional lecture-based classes [40].

2.2 Participants

The participants were 41 students from two classes of a public university from the North of Portugal divided in two groups of the 3rd year college, one undergraduate course in Psychology (control group with 22 students) and the other in Basic Education (experimental group with 19 students). Regarding gender, 87.8% were females and ages ranged between 19 and 37 (M = 20.8; SD = 3.18).

2.3 Measures

The measure used to evaluate the development of critical thinking came up from the application and results of a Critical Thinking Test (CTT) elaborated by the authors and already validated for the Portuguese higher education population [41]. The CTT presents a common problem situation of daily life, in which problematic circumstances can be identified. The respondent is asked to answer a set of six questions, which refer to different cognitive tasks which require for their appreciation and resolution, the use of a critical thinking skill, taking in consideration the Bloom's taxonomy reviewed by the reference [42] and [13] critical thinking skills classification: (i) interpretation, (ii) analysis, (iii) explanation, (iv) evaluation, (v) synthesis and (vi) production/creation.

In question 1 the respondent is asked to identify the problem contained in the described situation in order to assess his/her capacity to interpret - understand and express the meaning of a wide variety of experiences, situations, data, events, judgments, conventions, beliefs, rules, procedures or criteria. In question number 2, the respondent is asked to identify and then compare solutions to solve the problem, to evaluate his/her analytical capacity - to present the main ideas and to relate them to each other, involving the decomposition of the material into its constituents' parts, and determine how the parties relate to each other and to the general structure of information. In question 3 the respondent is asked to select the best solution and to present an argument in its defense, in order to evaluate his/her capacity for explanation - to present the result of his own reasoning and to justify this reasoning with valid arguments. In question 4 the respondent is asked to evaluate the quality of the defended solution in order to evaluate his/her capacity for evaluation - to evaluate the credibility of arguments, representations, descriptions of perceptions, experiences, situations, evaluations, beliefs or personal opinions, as well as the inferential relationships between arguments, descriptions, questions or other forms of representation. Finally, in question number 5, the respondent is asked to propose strategies to maximize the quality of the solution he or she advocates, to evaluate his/her capacity for synthesis - to create a new idea from other ideas and to build knowledge based on the collection and information processing. Each of the five questions are answered openly by respondents on a response sheet.

After the test, the responses were scored from an evaluation rubric. For each of the five questions relating to a critical thinking skill under evaluation, the evaluator scored the student's response on a four-point scale: (3 points), (2 points), (1 point) and (0 points). These points were attributed, according to the critical thinking skill evaluated by each question, in logic of quality and quantity (Table 1).

The test total score ranges from 0 to 25 points. The inter-judge reliability (Cohen kappa coefficient) ranged between .76 and .93. The results overall showed sufficient to high inter-rater reliabilities both at the item and the total score level [43].

3 Procedures

To determine how cooperative learning effectively improved high students' critical-thinking skills, a 13-weeks period of experimental instruction (in a total of 13 lessons, lasting 120 min each) focusing on learning critical thinking took place in the experimental group. At the beginning of the semester (1) The teacher organized heterogeneous groups of four or five students; (2) He assigned roles to the different members of the group. The roles were rotating and were adjusted to the activities goals; (3) In the 13 lessons, the students in cooperative groups (3.a.) analyzed pedagogical scenarios, which entailed problem solving and (3.b.) read and analyzed papers on teaching-learning methods in which they had to develop the respective concept maps; (4) Works were exchanged between groups in order to give and receive feedback (peer feedback); (5) The teacher gave feedback to the work of each group after peer feedback; (6) Students improved the work carried out, incorporating feedback from colleagues (peer feedback) and teacher; (7) A final oral presentation was carried out by each group to the whole class; (8) A reflection on the functioning of the group (group process), strengths, weaknesses, and improvement strategies was made.

For the control group, the lessons were explained using a more traditional lecture-based approach in which the preponderant role was assigned to the teacher. Both, the experimental group and the control group took the pretest in the first week and completed the posttest (same test as the pretest) in week 13.

3.1 Ethical Considerations

This project followed the ethical requirements of the EFPA - European Federation of Psychologists 'Associations, as well as of the OPP - Portuguese Psychologists' Order. All ethical principles have been respected, ensuring that all participants were familiarized and accepted the principles of informed consent, voluntary participation and the confidentiality of their responses.

Table 1. Scoring rubric to each dimension of critical thinking evaluated.

Dimensions	Criteria		Score
1. Interpretation	The answer is complete, well-founded and organized		3
	The answer is incomplete, poorly grounded and poorly organized		2
	The answer is incomplete, unsubstantiated and confused		1
	The answer is entirely incorrect		0
2. Analysis	The answer is complete, well-founded and organized		3
	The answer is incomplete, poorly grounded and poorly organized		2
	The answer is incomplete, unsubstantiated and confused		1
	The answer is entirely incorrect		0
3. Explanation	The argument contained in the answer is coherent and has two or more justificatory premises		3
	The argument contained in the answer is coherent and has a justification		2
	The argument contained in the answer is inconsistent		1
	The argument contained in the answer is invalid		0
4. Evaluation	The answer is consistent and presents at least three weaknesses		3
	The answer is consistent and/or presents two weaknesses		2
	The answer is inconsistent and/or presents one weakness		1
	The answer presents invalid and/or doesn't present weaknesses		0
5. Synthesis	The argument contained in the answer consistently improve all the weaknesses of a solution or create a new solution		3
	The argument contained in the answer is presented in a coherent way and improves some of the weaknesses of a solution		2
	The argument contained in the answer is inconsistent with the weaknesses of the related solution		1
	The argument contained in the answer doesn't improve the identified weaknesses		0
6. Production/creation	Fluency	Presents more than two solutions	3
		Presents two solutions	2
		Presents one solution	1
		Doesn't answer	0
	Flexibility	The solutions presented serve to solve the problem	2
		The solution presented serves to solve the problem or some of the solutions serve to solve the problem	1

(*continued*)

Table 1. (*continued*)

Dimensions	Criteria		Score
		None of the solutions serve to solve the problem or are equal to the ones proposed in the text	0
	Originality	At least one of the solutions presented is new and the others are not based on assumptions similar to those presented or are still less mentioned	3
		The solutions presented that serve to solve the problem are new and much referred	2
		The solutions presented are modifications or improvements to the ones proposed in the text	1
		The solutions presented the same of those that are proposed in the text	0

4 Results and Discussion

The data analysis was carried-out using SPSS – Statistical Package for Social Sciences (version 22.0). In all analyzes, the level of statistical significance considered was 5%.

4.1 Differential Analysis of Critical Thinking Between Control and Experimental Groups in Pre-test

A paired-samples t-test was conducted to evaluate if there were significant differences between control and experimental groups regarding critical thinking. Results (Table 2) show that there were significant differences $t(39) = -2.505$, $p < .017$] between the control group ($M = 13.68$; $SD = 2.950$) which had higher score results and the experimental group ($M = 11.37$; $SD = 2.950$). The eta squared statistic (.025) indicated a small effect size.

Table 2. Differential analysis of critical thinking between control and experimental groups in pretest.

Groups	N	Mean	SD	*t*	*p*
Experimental	19	11.37	2.948	−2.505	.017
Control	22	13.68	2.950		

4.2 Differential Analysis of Critical Thinking Between Control and Experimental Groups in Posttest

A paired-samples t-test (Table 3) was conducted to evaluate the impact of the intervention on students' scores on the Critical Thinking Test (CTT). There was a statistically significant increase in scores from pre-test ($M = 11.37$, $SD = 2.95$) to post-test

[M = 16.53, SD = 3.27, t(18) = −6.54, p < .001] in the experimental group. The results indicated a large effect size (d = 1.66).

Table 3. Comparison of score means, standard deviations, mean differences, effect size from the critical thinking pre to post-test between experimental and control groups.

Groups	Critical Thinking Test	N	Mean	SD	Mean differences	Effect size (Cohen d)
Experimental	Pre-test	19	11.37	2.95	t(18) = −6.54, p < .001	d = 1.66
	Post-test		16.53	3.27		
Control	Pre-test	22	13.68	2.95	t(21) = 1.86, p = 0.76	d = −0.5
	Post-test		12.05	3.54		

These results seem to indicate that the diverse educational activities carried out with the cooperative learning approach contributed for the development of students' critical thinking. These activities allowed students to be involved in dialogic interaction processes, either within or between cooperative groups, when students have to negotiate their point of view [44–46]. These results are in line with the studies by the references [47–49] and [50] who showed that students improve their critical thinking skills working in cooperative groups as compared when they work individually using more traditional methods. While it encourages active participation in the acquisition of knowledge and promotes interaction with others, cooperative learning favors the development of individual relevant reflection skills. When the students have the opportunity to interact with different perspectives and opinions about the work at stake, as it happens with cooperative learning, they analyze critically the ideas, comment, compare the work, give, and receive feedback that can be used to enhance their critical thinking skills [51].

According to the reference [52] in cooperative groups, students feel free to risk, challenge, and question. There is student-to-student interaction focused on information processing, where students consider the ideas, contributions, and arguments of peers; teachers don't "tell", rather, they help students critically analyze ideas; students are encouraged to become active learners rather than passive recipients of information; and students take responsibility for their own thinking and learning [53]. As the reference [51] state, adolescents are able to develop higher order thinking skills (formal operations) through internalizing the viewpoints of other people, which takes place during dialogues with others. As the reference [24] explains that the process of making sense of the world is profoundly influenced by ones' interactions and perceptions of one's environment, followed by the reference [54] who stresses the potential students have to raise themselves to a higher intellectual level of development through collaboration. Discussion helps develop critical thinking because students do the thinking and there is an opportunity for them to check their thinking against each other [55, 56].

Results of Table 4 show that in the experimental group, 84% of the students raised their critical thinking score from pre-test to post-test (Average gain of 5.16 points); in the control group, only 36.3% of the students increased their scores from pre-test to post-test (decreased of −1.63 points). The critical thinking skills main gains in the experimental group were in the explanation, synthesis and flexibility (production/creation) skills.

Table 4. Means, standard deviations and mean differences in critical thinking skills test for pre- and post-test for experimental and control groups.

Experimental group (N = 19)						
Question	CT skill	M pre-test	SD	M post-test	SD	M difference
1	Interpretation	1.26	1.04	1.74	.73	.48
2a	Analysis	2.11	.31	2.16	.5	.05
2b	Analysis	1.05	.4	1.63	.59	.58
3	Explanation	1.26	.99	2.42	.96	1.16
4	Evaluation	.68	.47	1.42	.69	.74
5	Synthesis	1.32	1.1	2.47	.96	1.15
6	Fluency	1.53	.69	1.42	.69	−.11
6	Flexibility	.95	.4	1.95	.78	1
6	Originality	1.16	.76	1.95	.8	.79
Score	CTT	11.37	2.95	16.53	3.27	5.16
Control group (N = 22)						
Question	CT skill	M pre-test	SD	M post-test	SD	M difference
1	Interpretation	1.09	1.06	1.36	1	.27
2a	Analysis	2.05	.375	2.23	.42	.18
2b	Analysis	.86	.71	1.05	.89	.19
3	Explanation	1.59	.66	1.81	.95	.22
4	Evaluation	1.05	.66	.95	.65	−.1
5	Synthesis	1.23	1.11	1.64	1.32	.41
6	Fluency	1.45	.67	.82	.5	−.63
6	Flexibility	1.77	.42	.77	.42	−1
6	Originality	2.27	.55	1.55	.91	−.72
Score	CTT	13.68	2.95	12.05	3.54	−1.63

The gains in these critical thinking skills are certainly due to the type of activities carried out during the semester. The resolution of pedagogical scenarios, the reading and analysis of scientific articles on pedagogical methods and the construction of conceptual maps involve essentially the mastery of analysis and synthesis skills. The fact that these activities were implemented in cooperative groups implied the need for the students to present their points of view and to explain them. They also had to be receptive to consider other points of view as valid, to argue and to counter-argument [29, 57, 58].

5 Conclusions

The aim of this study was to analyze if there were any statistically significant differences between the critical thinking skills development of the college students involved in a cooperative learning approach, compared with those submitted to a more traditional lecture-based classroom teaching.

Using the Critical Thinking Test, in the pre-test phase, there was a statistically significant difference in the mean between the control group and the experimental group, the total score being higher in the control group. In the post-test phase, the mean of the experimental group increased significantly compared to the control group's one, reflecting an increase of the critical thinking skills from the students belonging to the experimental group.

On the other hand, the skills with more significant raise in the experimental group (explanation, synthesis and flexibility (production/creation skills) seem to have been improved due to the features of the classroom activities involved as well as the active student participation, meaningful interaction with material, and student-to-student verbal interaction. The practical implications of the results of this study are clear. Professors may be able to increase student critical thinking skills by including cooperative learning approaches. They will thus enhance an important part of students' education contributing for their effective integration into society and the workplace as "better" thinking future citizens.

In future work, it would be useful to investigate the impact of the cooperative learning approach throughout the academic course, comparing the gains in critical thinking between students who learn with cooperative approaches and others who do not. Another important research concern should tackle the effects of cooperative learning on the development of critical thinking dispositions versus a more traditional pedagogical approach.

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Students' Study Routines, Learning Preferences and Self-regulation: Are They Related?

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Abstract. Good self-regulatory skills and study habits seem to be essential conditions to students' engagement with active learning approaches, critical thinking development and academic achievement. This exploratory research study aimed to assess possible relationships between students' self-regulation, learning preferences and study routines towards their engagement in student-centered approaches. Seventy-nine undergraduate students from an integrated master program in Veterinary Medicine were surveyed at the beginning of a redesigned course. The Tangney' short form of Self-Control Scale was used to measure students' self-regulation, and a questionnaire with close and open-ended questions was applied to assess students' study routines and learning preferences. The results revealed some associations between gender and self-regulation, and between self-regulation, study routines and learning preferences for the type class format. Female students presented higher self-regulation scores than male ones. Students with regular self-study habits also had higher self-regulation scores. Further research will analyze the relationship between students' self-regulation, academic performance and critical thinking development, as well as the impact of active learning approaches in students' study routines or learning preferences.

Keywords: Self-regulation · Study routines · Learning preferences · Active learning · Critical thinking

1 Introduction

The adoption of active learning strategies increases students' engagement, high-order thinking and memory retention [1]. With the implementation of the Bologna process, a shift in learning paradigm challenges higher education institutions to move from traditional lecture-based approaches to a more student-centered learning – in which the teacher is responsible to ensure the quality of the learning process encouraging students to assume an active role in the achievement of the expected learning outcomes [2]. For that purpose, students need to be responsible and autonomously involved in their own learning, requiring high levels of motivation, confidence and self-regulation [3].

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Despite the implementation of this new paradigm in Portuguese universities, between 2006 and 2009, institutions and teachers frequently claim different barriers and difficulties, like a large student/staff ratio and the lack of students' engagement in the learning process [4]. As a consequence, the traditional teaching approach remains in practice, representing a passive transfer of knowledge. Students' assessment is often based on knowledge memorization and retrieval [5]. In parallel, the traditional teaching approach encompasses increased failure rates, reduced levels of conceptual understanding, and high absenteeism, which represents a major concern for universities [6]. To counterpoise, universities request the use of active learning strategies as a form to motivate students and to revert the effects of the failure rates and disinterest.

Students in tertiary education are expected to possess the competence to sustain their cognition, the positive motivation and behavior to pursuit their academic and professional goals. However, some university students enter academic programs poorly equipped with self-regulation skills [7]. The inability to develop such skills is often at the origin of disinterest for learning and increasing failure rates. To support and facilitate students' active learning and success, it is necessary to investigate the influencing factors shaping the students' engagement in the learning process.

Students' motivation and engagement to learn can be affected by diverse factors, such as the instructor teaching approach, the type and quality of learning spaces, organizational constraints, or even the existence of personal beliefs [6, 8]. Any of those factors may represent a barrier that needs to be overcome. Therefore, it is important the analysis of students' self-regulation and learning strategies– assuming that they are intertwined with motivation and engagement [9].

Self-regulation can be defined as "*the self-directive process by which learners transform their mental abilities into academic skills*" [10, p. 65]. It relates, but is not limited, to goal setting, time management, task strategies, environment structuring, and help-seeking [11]. Self-regulation may also be related to deepness of the learning approach and the development of an optimistic learning strategy [9]. Evidence suggests that a large number of higher education students lack self-regulation learning skills [12], which reflects in an inability to effectively monitor their learning outcomes. According to [13], it is possible that qualitative and quantitative differences exist between the self-regulatory processes of effective and less effective self-regulated students. However, the relations between self-regulation, engagement and the success of learning are still scantily clarified. However, a clear, direct relationship between self-regulation and the learning success is still controversial, suggesting that self-regulation effects on learning are a complex phenomenon [9].

Moreover, [3] defend that student's engagement in learning varies with the learning style, making students dependent of its passivity or activity. Since the active learning requires the students' involvement in "doing things" and thinking about what they are doing, one question remains: may the students' learning preferences, study habits and self-regulation abilities affect the way they involve on active learning activities and therefore their academic achievement and the development of their high-order thinking?

This exploratory research study aimed to assess how students' self-regulation, study routines and learning preferences might be dependent in 79 undergraduate students of the course of Animal Reproduction (sixth semester in the Veterinary Medicine integrated master degree at UTAD, Portugal). In particular, we tried to collect information on potential relationships between these three variables. Thus, our results can be useful when designing and structuring pedagogical interventions to support learners' self-regulation and subdue inefficiencies in their natural tendencies.

1.1 Context and Course Background

The course of Animal Reproduction is located in the 2nd semester of the 3rd year of the integrated master in Veterinary Medicine, together with other semiotics subjects, previously to the clinical subjects. Two main learning goals were presented to students: (1) to acquire knowledge over the reproductive function in the male and female of domestic species, empowering the ability to analyze a situation, synthetize information and intervene in the monitoring of fertility in those animals; (2) to develop technical procedures needed to practitioners working in this field, enhancing the autonomy, self-confidence and the awareness of diverse values (e.g., social, cultural or economic) and ethical concerns applied to practice.

Until the last academic year (2016/17), generally, the theoretical classes were taught using traditional expositive methods, where the instructor passively transferred information in the form of a lecture to an audience presenting different levels of attention/interest. In the past two years, when discussing with the students the possibility to change the learning strategies used in the theoretical classes into more student-centered ones, they were reluctant to accept the proposed changes like in other courses during the program [14]. Contrasting, the practical classes in this grade are usually more active since they apply specific procedures related to the professional practice.

Despite the students' reluctance, the changes were introduced in the current academic year, and the feelings/expectations of the students were collected through a survey at the beginning of the classes. Then, in a small briefing on the course contents, methods of learning, and expected outcomes, the teacher explained the gains in knowledge and critical thinking associated with the use of active learning strategies and exposed the methodologies to be used in the theoretical classes. Students were also informed that in this course, the assessment would measure both the scientific knowledge and the ability to develop higher levels of thinking.

In general, the theoretical classes now follow the flipped classroom methodology [15]. This methodology assumes that students prepare the course-related topics in advance – self-study/individual work - being the self-learning activities directed through the Moodle online platform, by the availability of supportive information. The student is therefore called to mobilize the knowledge acquired previously (during the self-study and in other courses) in the analysis of subject-related situations, in the discussion and summarization of contents and in the proposal of corrective or alternative measures to mitigate situations. Here, the main goal is to foster students' critical thinking skills. In the classroom, the students contact with practical situations extracted from the professional practice, which they have to analyze, propose a justification for the situation, select procedures and/or propose a corrective intervention to restore or maximize the fertility of the animal/group/farm.

In the practical classes, the learning purposes are mainly directed to the execution of techniques crucial to the professional practice in this field. The classes are organized in small groups and taught in different spaces (e.g., at the laboratory, at the University

Veterinary Hospital) by follow-up of casuistry or simulation of clinical situations, in-class. Besides the basic training in technical procedures, practical classes also aim to develop advanced cognitive skills, by the analysis of data or results gathered during interventions, by establishing inferences and assessing arguments/data/information, as well as by the ability to communicate efficiently with colleagues or operators, to explain data, to decide and share it with third parts.

There are also tutorial classes. The tutorial classes are mandatory contact hours and are scattered through the semester. This kind of classes aims to reinforce learning, direct the teacher intervention towards topics that are more difficult to understand. Similar strategies to those described above are used.

2 Methods

This paper presents the results of an exploratory research study [16]. It explores the way students' self-regulation, study routines and learning preferences are related at the beginning of a redesigned course proposal which promotes a more active learning approach. As a work in progress, it allowed us to get a first insight to develop further research (e.g., quasi-experimental), that can enable a deeper analysis of the relationship between these variables with other key indicators, such as the students' academic achievement or critical thinking development.

Thus, at the beginning of the semester students were requested to fill a short form of the Self-Control Scale developed by [17], at the end of the first class. This questionnaire contains 13 items allowing to establish people's ability to exercise self-control, alter their emotions and thoughts, and in particular to override temptations and refrain from acting [18]. From the collected filled forms, one was in blank and two were named after fictional personages, and therefore were excluded from the analysis.

In addition, students were also asked to complete an online questionnaire survey. It was composed of 10 questions regarding their commonly used study routines until then for their academic achievements and on their preferences for the theoretical and practical classes. In the first set of questions, three close questions regarded the way students usually study for assessment and if some self-learning before the classes was done, and an open-question asked the reasons for their answers; in a second set, two closed questions asked their preferences for the pedagogical approach in theoretical and practical classes and one open question asked the reasons for their answers. On three additional open questions, students were requested to share their expectations about the course: what could be their contribution to the course success, and what they would like that the teacher knew about them. This questionnaire was made available through the Moodle platform, and the students had one week to fill it. In both cases, by submitting their questionnaire or self-rating scale the students were aware of giving consent for the anonymous use of data.

After matching the two instruments, using the students' name for pairing, identifications were removed before sending data for analysis. The responses to the survey on the study routines were analyzed qualitatively and quantitatively, using the SPSS software, version 25. For quantitative data, differences were tested by Student t-test for independent samples, the significance set at $\alpha = 0.05$. The final score for the self-control survey was used to test an association between the students' self-regulation score and their disposition to participate in active learning strategies. Quantitative data is presented as mean ± SEM.

3 Results and Discussion

Of a total of 92 students enrolled in the Course, nine did not fill either the self-control form or the online survey. From a total of 83 students who submitted either the self-rating scale or the online survey, 63 (75.9%) were women (Table 1).

Table 1. Characterization of the gender of participants[a].

Respondents	Filled the survey	Self-regulation scale (in-class)	Online survey
Women	Yes	57	62
	No	6	1
Men	Yes	17	17
	No	3	3
Total		74	79

[a.] As the two questionnaires were filled at different moments, an overlapping of 93,7% between the two questionnaires was achieved.

Regarding the scores of the short form of the Tangney' Self-control Scale (Table 2), the mean score for the participants (n = 73) was 43.62 ± 0.95 (range, 26 to 60). Higher scores were found in women compared to men respondents (44.88 ± 1.03 – range, 26 to 60 *vs*. 39.20 ± 1.80 – range, 26 to 56, respectively; p = 0.011; Fig. 1).

Table 2. Characterization of the gender of participants.

Respondents	*n*	Average ± SEM	Median	Q1	Q3
Women	56	44.88 ± 1.03	45.00	40.00	49.00
Men	17	39.47 ± 2.02	40.00	36.00	44.00
Totals	73	43.62 ± 0.95	43.00	39.00	48.50

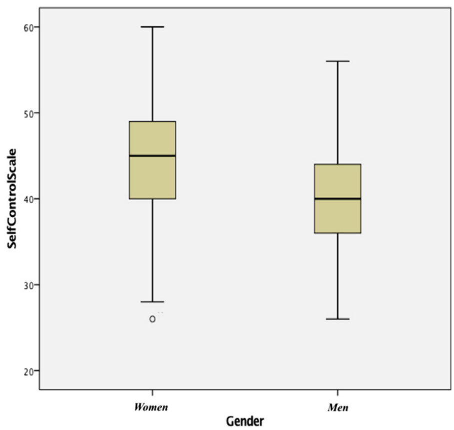

Fig. 1. Distribution of self-control scores in respondents according to gender.

Respecting to the participants' study routines, most students regularly study for the practical classes but concentrate the study for the theoretical (64.56%; 51/79), while 18.99% (15/79) usually concentrate their study a few days before assessment in either the theoretical and practical topics, and 16.46% (13/79) regularly study throughout the semester.

Analyzing data collected from students submitting the two tests (n = 70), it was found that the self-control scale was slightly lower ($p = 0.046$; Table 3) in students mentioning to concentrate their study in the few days before assessment (39.15 ± 2.28; n = 13) compared with that of students studying regularly for the practical's, but not for the theoretical classes (44.10 ± 1.08; n = 49), or those who study regularly for both the theoretical and practical classes (46.50 ± 1.76; n = 8).

When inquired if they prepared themselves before classes, most students referred preparing the practical classes with self-study, but not the theoretical ones (56.69% vs. 13.92%, respectively). Among the reasons presented for their routines in students concentrating their study a few days before the assessment, the most frequently pointed out reasons were "*the large workload*", the unavailability of lecture notes on time (even when the list of recommended books is communicated in the learning platform), *"(…) it's easier to have the teacher explaining the topic before our study*", the fact that *"(…) the teacher says everything that is needed*", and the fact that the students believes it unnecessary or not a good method for him/her.

Table 3. Self-control scores according to the students' study routines.

Study routine	*n*	Average ± SEM	Median	Q1	Q3
Concentrated for both theoretical and practical classes	13	39.15 ± 2.28^{a}	39.00	36.00	45.00
Concentrate for theoretical but not for practical classes	49	$44.10 \pm 1.08^{a,b}$	40.00	36.00	48.00
Study regularly for theoretical and practical classes	8	46.50 ± 1.76^{b}	47.00	43.50	49.50

Within a column, different superscripts represent statistical differences at $p < 0.05$

For students that concentrate the study only in the theoretical topics, while preparing the practices in advance, the most common presented arguments were that it was easier to understand/achieve a good performance in the practical work if prepared in advanced, and the limited time available to prepare both the practical and theoretical classes, as well as *"(…) is easier to take notes and listen to the professor in the theoretical lectures, and study afterwards*" and *"(…) it is better to first listen to the teacher*". Other reasons presented included the higher interest students have in practical classes compared to theoretical, or the fact that students don't feel the need to a preparatory self-study for the theoretical classes because they are expositive.

Students that prepare themselves before each class often argue that they achieve "*(…) better understanding of the topics*", *"(…) to avoid accumulation of the study material*", or "*(…) to get better grades*".

The second set of questions showed that most of the students prefer the teacher to demonstrate the procedures to be developed during the practical classes (79.75%; 62/79); 17.72% (14/79) prefer the teacher present a short theoretical background review in the beginning of the practical classes, while only 2.53% (2/79) prefer to start the practical classes hands-on. No differences were found in the self-control scale among students in the three groups.

Regarding the format of the theoretical classes, the majority of students prefer them to be expositive (58,23%; 46/79), 22.78% (18/79) would like them to be developed as a discussion between students and the teacher, while 18.99% (15/79) would prefer that classes detailed the most difficult topics in a subject. No student selected the option for non-in presence/virtual classes. Although non-significantly (p = 0.072), slightly higher self-control scores existed in the group that prefer expositive classes (Table 4).

Table 4. Self-control scores according to the students' preferences for the format of theoretical classes.

	n	Average ± SEM	Median	Q1	Q3
Expositive	41	45.22 ± 1.28	45.00	40.00	50.00
Discussion between teacher and students	18	40,83 ± 1.13	41.00	49.00	44.00
Focusing on more difficult issues of a topic	11	41.18 ± 2.23	41.00	38.50	47.00

The most frequently invoked reasons to sustain their preferences on expositive classes were *"(…) is easier to understand what and how to do (something) when the teachers show first*", "*(…) I understand better when it is the teacher explaining (than when I prepare myself at home)", "(…) I feel that I understand better the topic when the teacher explains it*" and "*without self-study before the classes, it is easier to have expositive classes*". Other students said *"(…) I prefer when the teacher shows how to work, because I am short-experienced*", and "*(…) even when we prepare ourselves at home, there are some issues more difficult to understand, so it is important to have expositive classes*". One student also argued that *"(…) for a better communication between the teacher and students, the teacher should previously show how to perform any task*".

On the other hand, students who prefer the classes to evolve as a discussion around a topic defend their preferences because *"(…) it is easier to understand, while expositive classes are boring*", "*(…) are more dynamic and participative*", "*(…) are more captivating*", and "*(…) they have a positive dynamic that facilitates absorbing knowledge*" and "*(…) they request (the student) to prepare himself in advance*".

Regarding the students who marked the acceptance of classes in which the teacher would focus on the more difficult topics of the syllabus, the reasons included "*(…) this would facilitate learning of more difficult issues*", and "*(…) the more difficult topics should be addressed in the class, as the easier ones could easily be learned at home*". One student argued that "*(…) these (classes) go against everything we are used to*".

Gender did not affect neither the study routines nor the preferences for different forms of the theoretical or practical classes.

In relation to their expectations towards the course, it was clear that students showed some inquisitive predisposition, focusing on the need and desire to learn mainly concrete knowledge (e.g., factual and conceptual), technical and practical skills within the specific domain. For this, students seem to be aware of the importance behind both theoretical and practical classes, of establishing an interdependence between them. Also, the majority considered that this course was essential for their professional life, representing an undeniable added valued in multiple scenarios, from clinical practice to the management of large-scale animal production. Even a smaller minority, who seemed to be less interested in this specific domain or without great expectations, showed openness to learn: "*I think that the course will be of great important to those who will work in farm animals medicine; however, it doesn't mean that who will work with other (animal) species wouldn't value it as well attending to the incertitude of the upcoming future*".

Additionally, students seemed to be highly committed to the course. They expressed it expecting to be more "*responsible*", "*diligent*", "*participative*", "*organized*", "*concentrated*", "*studious*", etc. They also presented some signals of intellectual modesty and humility, being aware of their own limitations in terms of cognitive or self-control abilities: "*I'm a person highly distracted but I struggle to obtain better results and do a good work*".

4 Conclusions, Limitations and Future Work

The aim of this 'work in progress' study was to analyze the students' self-regulation, learning preferences and study routines in an initial phase of the Animal Reproduction course at the Veterinary Medicine integrated master degree. Despite its exploratory nature, the results allowed us to characterize the students' profile in relation to these aspects and draw some questions for further research that will be carried-out during and at the end of the course.

Our findings suggest some significant relationship between gender and self-regulation. Female students seem to have higher self-regulation than male ones. This agrees with previous studies [12, 19, 20], suggesting that woman at this particular age are more mature and self-regulated, result that has been associated with a willingness of female students to delay gratification to increase the chances of getting a good mark [21]. Further research should also attend to the gender variable in order to examine how active learning activities can influence these abilities in female or male students.

Secondly, study routines and self-regulation seem also to be linked. In fact, students presenting higher self-regulation scores also show systematic and ongoing habits to study and prepare themselves before the classes throughout the semester. On the contrary, those with lower self-regulation scores concentrate the study mainly for the assessment in the theoretical topics, which might indicate a lack of abilities in time management. In addition, since theoretical classes are often lecture-based and teacher-centered, students seem to undervalued the need to be prepared in advance contrasting to the practical classes where they need to perform procedures requesting previous study (e.g., protocols, ultrasound assessment, physical exams). Therefore, study routines are apparently affected by the type of teaching approaches adopted by the teacher.

This is in agreement with other authors, who found that stronger self-regulated students are able to change learning strategies in response to the requirements of a course [12].

Regarding the students' learning preferences, the lecture-based format seems to be more preferred than the student-centered one, like discussion or hands-on learning. This could be related with different factors, such as students' self-confidence, explanatory and communication abilities (e.g., to engage in a debate with peers, presenting arguments and debating different approaches to analyze professional cases or situations), or even due the learning culture of "easiness" that still remains in our universities, as previously suggested [5, 6]. Future studies would be needed to evaluate if the students' learning preferences are determined by the format of the classes (teacher-centered vs student-centered approaches).

In future work and at the end of the course, additional issues will be addressed, like seeking the establishment of a relationship between the students' self-regulation and the academic performance, critical thinking development, the changes in study routines or learning preferences.

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Teachers' Thoughts About How Critical Thinking Is a Part of Their Classes

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Abstract. The project CRITHINKEDU – Critical thinking across higher education curricula, financed by the European Commission has the purpose to search good practices related to critical thinking integration into higher education curricula. The following article presents a collection of five interviews with higher education professors from Humanities and STEM, in Romania. This paper presents and compares Romanian teachers' opinions with those found by the other partners in the project. The help that professors need is on learning materials, assessment and teacher training. Interventions should aim teacher training, but also the educational policy of the universities related to teaching quality assurance, imbedding CT into educational programs design and look for it when evaluating an educational program.

Keywords: Critical thinking · Higher education curriculum · Critical thinking dispositions · Humanities · STEM

1 Introduction

It is important to begin with the presentation of the project from which this paper draws its content and aims. CRITHINKEDU "Critical thinking across the European higher education curricula", funded by the European Commission under the Erasmus+ Programme, reference number 2016-1PT01-KA203-022808, is a partnership from 9 countries: Belgium, Czech Republic, Greece, Ireland, Italy, Lithuania, Portugal, Romania and Spain. The partnership was constituted by invitations sent to all authors identified by the applicant institution, University Tras-os-Montes e Alto Douro, Portugal.

The authors had published papers concerning critical thinking as domain specific and context bounded skill. The countries and institutions represented in this project are those that accepted the challenge to pursue the research and intervention topic proposed in the application (critical thinking and domain specificity). It includes contributions from 11 European Higher Education Institutions (EHEI) and over 59 scholars and experts from different fields (Biomedical Sciences, STEM – Science, Technology, Engineering and Mathematics, Social Sciences, and Humanities).

For the second intellectual output of CRITHINKEDU, named "A European review on critical thinking educational practices in higher education institutions" [2], led by the University of Santiago de Compostela (USC), partner institutions had to research

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for interventions concerning critical thinking (CT) in higher education presented in the literature. After this stage, *partners had to interview teachers*, for a better image of pedagogical and didactical practices in European universities.

2 Methodology

The methodological design was a common enterprise, all partners from CRITHINKEDU project agreed to have a collection of interviews to find out what teachers are thinking about CT and how they are integrating it into their classes. The general hypothesis of the project is that there are differences among the disciplines concerning CT integration, each discipline having different needs and specific ways of CT embedding. And there is an assumption, which will not be explored: the CT skills and dispositions are better developed embedded and not through stand-alone class. The design has many stages and six outputs. This paper presents the second output, interviews with teachers, and it has the following steps [3]:

2.1 Design of Interviews

Open-ended questions were formulated, covering several CT dimensions inspired by Facione's framework [2, 4]. The content of the interview protocol was built upon Paul, Elder and Bartell [8] interviews on teacher preparation for instruction in critical thinking. CT concept, intent CT aims, overall approach, type of intervention, teaching strategies, learning materials, assessment, challenges, teacher training/instruction on CT and institutional barriers while promoting CT. These authors conducted interviews with education and subject-matter faculty in private and public colleges and universities, addressing a number of key aspects of teaching practices in CT. Some of these questions were adapted and used in this protocol, as follows: 1. How would you explain to me your concept/idea of CT? 2. What particular aspects of CT do you believe are most important for your students to develop? And why? 3. Could you describe the practices (approaches/strategies/interventions) that you use in your classroom to foster CT? Please, give an example 4. Which learning materials do you use to promote CT in your classroom? 5. Do you assess CT abilities of your students? And how? 6. What challenges do you experience when developing CT in your students? How do you try to address them? 7. What type of instruction (or other) do you think should be provided to your colleagues to support the development of their CT teaching practices? 8. Are there any institutional barriers that limit the promotion of CT education?

2.2 Sampling Design and Procedure

CRITHINKEDU partners reached to a consensus to select five university teachers from diverse fields, using the categorization: STEM, Humanities, Social Sciences and Biomedical Sciences.

Participants' characteristics are described in Table 1 (*Romanian Participants to the Interviews*).

Table 1. Participants to the interview

Name (initials)	Domain	Age	Gender	Working experience
A. I.	STEM (architecture)	51	M	25
M.A.	STEM (chemistry)	63	M	30
S.C.	Humanities (philosophy)	45	M	20
D.B.	Humanities (ethics)	38	M	15
E.A.	Humanities (archaeology)	62	M	33

2.3 Data Collection

Five protocol interviews were collected. All interviews were audio and video recorded, and then transcribed for analysis.

2.4 Data Analysis

The transcriptions of interviews were submitted to qualitative content analysis. All teachers' responses were analyzed, question-by question following these 4 stages as in [3]:

(a) Decontextualization (Break down the text into smaller meaning units): researchers got familiarized with the data and read through the transcript to obtain the sense of the whole, before it could be broken down into smaller meaning units. By "meaning units" we refer to the constellation of sentences or paragraphs containing aspects related to each other, covering different dimensions of CT addressed in the interview.

(b) Recontextualisation: after the meaning units were identified in the transcript, we confirmed whether all aspects of the content had been covered.

(c) Coding in pre-established categories: teachers' responses were coded into the main categories and subcategories defined previously. The rubric used for the analysis of the literature reviewed served this goal, although two more dimensions were added: CT instruction in teachers' training and institutional barriers.

(d) Description of the results and quotes: results were illustrated with quotes from interviews in order to provide readers with a clear idea about how university teachers promote CT in their classes.

2.5 Data Assessment

Collected data were assessed with the method of content analysis, based on Facione's research tool for CT dispositions [2, 4], which recognizes seven dispositions (truth-seeking, open-mindedness, analyticity, systematicity, self-confidence, inquisitiveness and cognitive maturity) and six core CT skills (interpretation, analysis, evaluation, inference, explanation, and self-regulation). In summary, the researchers assessed the teachers' answers in the light of their CT thinking dispositions, attempting to extract elements that exhibit teachers' dispositions while they were commenting on the fields related to the project.

CT instructional approach is seen as in [5], categorizing the various approaches to CT instruction as general, infusion, immersion, and mixed. In the general approach, CT is taught separately from the presentation of the content of an existing subject-matter.

The infusion approach is a "deep, thoughtful, a well-understood subject matter instruction in which students are encouraged to think critically in the subject" [7: 5]. It attempts to integrate CT instruction in standard subject-matter instruction and makes the general principles of CT explicit to the students. This approach stems from debates concerning whether a generalist or specific method is the most effective way to teach CT in HE.

The immersion approach also tries to incorporate CT within standard subject matter instruction. However, general CT principles and procedures are not made explicit to students.

The mixed approach, named by Sternberg [9], consists of a combination of the general approach with either the infusion or immersion approach. In the mixed approach, there is a separate thread or course aimed at teaching general principles of CT, but students are also involved in subject-specific CT [10].

The type of intervention is modeled after Abrami, Bernard, Borokhovski, Waddington, Wade and Persson [1] categorization of instruction interventions. These authors expanded the analysis beyond a single instructional classification scheme and offered a fine-grained approach, which might explain more of the variability in CT outcomes, and may highlight especially effective instructional approaches.

CT Teaching Strategies. Ennis [6] describes two basics teaching methods for promoting CT, the Lecture-Discussion Teaching (LDT) and the Problem-Based Learning (PBL), which contrast with each other. LDT is the most common approach to college teaching [6]. There is a lecture (usually accompanied by some reading in a textbook) presenting one or more aspects of the subject-matter, followed by a discussion section (or a discussion at the end of the period in which the lecture was presented). PBL method calls for dealing with a subject-matter issue, usually requiring investigating, developing, testing, and discussing of hypotheses or solutions and possible alternatives.

3 Results and Discussions

The conception or definition of CT revealed by the interviews is substantive: they see CT as a set of skills and as dispositions to reasoning. More skills were mentioned, than dispositions, with a surprising total emphasis of dispositions in S.C. (philosopher) interview, although we can guess the skills embedded in the definition. Some beautiful illustrations are: "Critical thinking, much like the Orthodox Christian concept of Trezvia (awareness of oneself on one's being in the world at all times, awaken or asleep), assists us, architects or citizens in general, in placing us into the world, while being aware of the process of place-making. I am trying to engage my peers, via architectural criticism, in explaining their experience, and my students, via courses and debates" (A.I. - architect). "It is both a mental attitude (to think of everything with your own mind), and a discipline akin to (informal) logic." (S.C. - philosopher).

And a total understanding of CT as a set of skills, in Chemistry: "I need that my students explain if it works and why or if it doesn't work and why. So, Chemistry is arguing pro or con some statements" (M.A. – chemist).

The results regarding CT definition are consonant with CRITHINKEDU report, but we can observe that a Humanistic education is aiming to dispositions and less to skills, as we shall observe in the following when we shall talk about what CT aims. "What Archaeology is trying to do is to put facts in order, without any ideology" (E.A. – Archaeology).

The aims, or what CT should do for us, put the professors into position to define what is the purpose of CT into their disciplines. Professor E.A. of Archaeology says that CT aims to demolish students' overconfidence in textbooks and what they learnt in high school, and in what professors are telling them: "[When talking about the past] a terrible thing is that we all are wrong to some extent" (E.A. – Archaeology).

In Chemistry CT is explanation and interpretation "in all applications, student must explain why something is so".

The philosophers are the representatives of the stand-alone class approach. S.C. and D.B. have similar opinions: "It is important for students to learn to defend their ideas with good arguments, to learn to clearly state and explain their own views, to learn to evaluate others' opinions and to identify errors in their arguments. Being curious and eager to know are other two things that critical thinking can encourage" (D.B.); "The attitude. It's the critical thinker stance" (S.C.).

Related to the overall approach [5, 6], the preferred method is immersion (incorporate CT within standard subject matter instruction, but general CT principles and procedures are not made explicit to students). Four out of five teachers say that they will challenge their students but will not explain anything related to CT or make students aware of CT tasks: "I am always trying (not always with complete success) to engage my students in debates on any given topic taught in class" (A.I. – architect). One professor supports general, stand-alone approach, philosopher S.C., and that is what he is teaching right now.

The learning outcomes are in line with the general CRITINKEDU report [3], all teachers mentioned dialogue and authentic situation as specific types of interventions [1], problem solving and discussion (argumentation) as teaching strategies. "I am picking up controversial issues of the day and I am trying to make them develop a more general position on similar aspects of their trade. But debates are the liveliest approach to developing CT" (A.I. – architect).

The learning materials category of analysis is poorly populated, only two out of five professors mentioned something: exercises (Chemistry) and textbooks (Philosophy). Also, the assessment is in deficit. One professor mentions nothing (Architecture), another says that he does not put CT into the assessment (Chemistry), the evaluation being qualitative, direct, over the semester ("I cannot put CT tasks into an exam. I cannot make the standard (the ready reckoner). But it is not bad, the exam is only a part of the activity, I can assess them continuously over the semester. But if I put CT on the exam and it is not clear what I want, that is bad" - M.A. – chemist). A much clearer answer is offered by professor S.C., who teaches CT to undergraduate level, and we find out that he assesses CT through student's class interventions (questions, remarks… etc.), their participation in debates, and a written argumentative final essay. This situation regarding assessment is similar to CRITHINKEDU report [3: 49], most teachers do not specify assessment methods. Or in professor E.A. "I don't think I have any success, or maybe not just right now. Maybe someday my students will remember what I taught them".

Teacher training is present: we have a "brown bag day" from Archaeology, where a more skillful peer can mentor young assistant, or an institutionalized solution, an association or a professional organization where teachers can address specific issues connected to CT classes (S.C. - Philosopher).

Challenges and institutional barriers are very diverse, like in the project's report [3: 49]. But the number of students as challenge doesn't appear, maybe because the domains don't have a lot of enrolled students in Romania. But the professors mention mentalities, organizational culture or "the island effect", a single class or a single professor who is doing CT class is not enough to make a valid change: "The main difficulty in developing students' critical thinking abilities is that other courses that they attend in the university are not helpful to develop their critical thinking abilities, but are rather focused on memorizing information. For this reason, students are not got used to critically tackle the topics" (D.B. – philosopher).

The interviewed teachers showed a deep and substantive conception of CT skills and dispositions, with a clear preference of skills development in Chemistry (STEM) and Architecture. Professors need help in understanding the fact that new pedagogical strategies acquisition will improve their performance and their assessment of CT skills and dispositions.

4 Research Limitations

The research methodology, a qualitative one, cannot make claims of generalizing conclusions, but this inconvenient is overcome by the fact that we have a more vivid image of teaching methods and theories or definitions teachers have. Another limitation is the fact that only male subjects were interviewed.

5 Conclusions

Most of this paper findings are in line with the main CRITHINKEDU report, the CT definition, aims, overall approach, learning outcomes, assessment. But learning materials and teacher training is not as well represented in Romanian teachers' interviews, in comparison to the European report. One professor mentions "the island effect", the fact that CT must be in all subjects in order to make a difference.

So the help that professors need consist of two categories: the one they are aware, presented in challenges and institutional barriers, and the one they are not aware: on learning materials, assessment and teacher training. Interventions should aim teacher training, but also the educational policy of the universities related to teaching quality assurance, imbedding CT into educational programs design and look for it when evaluating an educational program.

6 Further Research

Good news comes from this respect. This paper is only the set of interviews from Romanian teachers.

We have two research reports (available here http://crithinkedu.utad.pt/en/resources/) on employers' opinion about CT and about European interventions, empirical studies, tackling CT development, and, coming next, a third report about teacher training program developed in Rome. We hope this report will become a seminal work that will inspire other educators in their everyday teaching activities.

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Stairway to the Stars: Comparing Health and Tourism Professionals Views About Critical Thinking

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Abstract. The relevance of critical thinking in the twenty-first century is indisputable. Although several authors discuss the need for preparing Health and Tourism students for careers in the twenty-first century some recognize the need to bridge the gap between the market needs – employers view – and the graduate profile – higher education institutions view. The CRITHINKEDU ERASMUS + project started questioning professionals about their views about the critical thinking needs in their areas. This work reports the results from the Portuguese focus group interviews in Health and Tourism areas. After a qualitative analysis, the outcomes for the Health area presented more mentions in critical thinking skills than the Tourism area. In turn, the Tourism area had more mentions in the critical thinking dispositions.

Keywords: Critical thinking · Skills · Dispositions · Health · Tourism · Professionals

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1 Introduction

Although several authors discuss the need for preparing Health and Tourism students for careers in the twenty-first century some recognize the need to bridge the gap between the market needs – employers view – and the graduate profile – higher education institutions (HEI) view. For instance, Wang et al. [1] states that "To ensure that education for a tourism career is relevant to employers within the sector, better communication between tourism education providers and the tourism sector is needed." Furthermore, some works refer the need for "soft-skills", such as communication (both oral and written; e.g. [2, 3]), teamwork (e.g. [3, 4]) and critical thinking (CT; e.g. [3, 6]). After the Millennium Conference in 2011 for the health professions, Huang et al. [5] discussed that "meaningful integration of critical thinking requires a complete shift from our current educational paradigm, which emphasizes diagnostic outcome over process." In addition, for tourism professionals, Stone and colleagues [6] concluded that "in order for future tourism professionals to be successful, they will need to be creative, innovative, and entrepreneurial – all of which require the ability to think critically."

In context of the 'CRITHINKEDU - Critical Thinking across the European Higher Education' ERASMUS+ project (https://goo.gl/RKa4vH), this work presents the results from the Portuguese focus group interviews in Health and Tourism areas. That required the collection of preliminary evidences of the CT skills and dispositions recognized as necessary by the professionals (employers) in these two professional areas. Briefly, the outcomes for both areas will be discussed.

2 Background

Several authors wrote about CT and as Lai [7] remarks "there is a notable lack of consensus regarding the definition of critical thinking". Since we aimed to distinguish the skills and dispositions referred by the Health and Tourism professionals the Facione's [8] framework was adopted as well as his CT definition [8, p. 2]:

> *"We understand critical thinking to be purposeful, self-regulatory judgment which results in interpretation, analysis, evaluation, and inference, as well as explanation of the evidential conceptual, methodological, criteriological, or contextual considerations upon which that judgment is based (...) The ideal critical thinker is habitually inquisitive, well-informed, trustful of reason, open-minded, flexible, fair-minded in evaluation, honest in facing personal biases, prudent in making judgments, willing to reconsider, clear about issues, orderly in complex matters, diligent in seeking relevant information, reasonable in the selection of criteria, focused in inquiry, and persistent in seeking results which are as precise as the subject and the circumstances of inquiry permit"*

In Faccione's definition, CT represents the systematic and the intentional use of different thinking skills towards a reasoned judgment, but it also enhances the availability and the engagement of the individual in the process. Figure 1 presents the tables that summarize the CT skills and Fig. 2 CT dispositions [8].

In what concerns the Health area, CT skills Krupat et al. [9] "conducted a qualitative study involving anonymous responses from medical school faculty members at five institutions" and referred that both "the 'process' and 'ability' [of some of the analyzed] definitions made consistent reference to higher-order mental activities (e.g.

SKILL	DESCRIPTION
Interpretation	To comprehend and express the meaning or significance of a wide variety of experiences, situations, data, events, judgments, conventions, beliefs, rules, procedures, or criteria
Analysis	To identify the intended and actual inferential relationships among statements, questions, concepts, descriptions, or other forms of representation intended to express belief, judgment, experiences, reasons, information, or opinions
Inference	To identify and secure elements needed to draw reasonable conclusions; to form conjectures and hypotheses; to consider relevant information and to reduce the consequences flowing from data, statements, principles, evidence, judgments, beliefs, opinions, concepts, descriptions, questions, or other forms of representation
Evaluation	To assess the credibility of statements or other representations that are accounts or descriptions of a person's perception, experience, situation, judgment, belief, or opinion; and to assess the logical strength of the actual or intended inferential relationships among statements, descriptions, questions, or other forms of representation
Explanation	To state and to justify that reasoning in terms of the evidential, conceptual, methodological, criteriological and contextual considerations upon which one's results were based; and to present one's reasoning in the form of cogent arguments”
Self-regulation	Self-consciously to monitor one's cognitive activities, the elements used in those activities, and the results obtained, particularly by applying skills in analysis, and evaluation to one's own inferential judgments with a view toward questioning, confirming, validating, or correcting either one's reasoning or one's results

Fig. 1. Table of Facione's (1990) skills description.

synthesis, analysis, interpretation) involved in making sense of information”. Also in their work Papp et al. [10] stated that an “accomplished critical thinker” “must be distinguished as being reliable, evidence based, and/or consistent with expert practice, and thus the ability to interpret information in the face of equivocal or conflicting data is a hallmark of critical thinking” and “the challenged thinker” should “firmly entrenched in a singular approach to thinking about the current problem and does not adjust when it would be appropriate to do so or when there are aspects of the problem that do not exactly fit the clinical situation”.

In what concerns the Tourism CT skills Stone et al. [6] report the use of case studies related to industry-specific problems with tourism students that “reflected a real situation as it actually happened or a real scenario in which portions were disguised for reasons of privacy”. In their discussion and implications, they pinpoint that the “strength of the study case learning goes beyond analysis and evaluation (…). However operationalizing (…) inference and induction skills is less common and more challenging (…)”.

DISPOSITION	DESCRIPTION
Truth-seeking	Being eager to seek the best knowledge in a given context, courageous about asking questions, and honest and objective about pursuing inquiry even if the findings do not support one' self-interests or one's preconceived opinions. The truth-seekers remain receptive considering additional facts, reasons, or perspectives even if this should necessitate changing one's mind on some issue. The truth-seekers evaluate new information and evidence.
Open-mindedness	Tolerant of divergent views and sensitive to the possibility of one's own bias. Valuing tolerance and understanding of the beliefs and lifestyles of others.
Analyticity	Prizing the application of reasoning and the use of evidence to resolve problems, anticipating potential conceptual or practical difficulties, and consistently being alert to the need to intervene.
Systematicity	Being organized, orderly, focused, and diligent in inquiry. Organized approaches to problem solving and decision-making are hallmarks of a thoughtful person regardless of the problem domain being addressed. The inclination to approach problems in an orderly and focused way.
Self-confidence	Trust the soundness of one's own reasoned judgments and inclination to lead others in the rational resolution of problems.
Inquisitiveness	One's intellectual curiosity and one's desire for learning even when the application of the knowledge is not readily apparent
Cognitive maturity	Approach to problems, inquiry, and decision making with a sense that some are necessarily ill structured, some situations admit of more than one plausible option, and many times judgments must be made based on standards, contexts, and evidence that preclude certainty. Making complex decisions involving multiple stakeholders, such as policy-oriented and ethical decision-making, particularly in time-pressured environments

Fig. 2. Table of Facione's (1990) dispositions description.

In the Health area Wangensteen et al. [11] quote that "nurses who are inquisitive, open-minded and systematic are more likely to use research findings in their work, which may contribute to high-quality nursing care". Krupat et al. [9] also referred that the interviewed doctors defined CT as "Both the 'process' and 'ability' definitions made consistent reference to higher-order mental activities (e.g. synthesis, analysis, interpretation) involved in making sense of information".

In the Tourism area, Suh et al. [2] refer some of characteristics appreciated the hotel managers: "written communication skills, team-building skills, conflict/dispute resolution skills, and setting goals/objectives" and the competencies for hotel managers included among others: "guest problem-solving skills, ethical standards, professional appearance, communication skills, customer relations skills, and employee relations skills". That is in the Tourism area some dispositions emerge even if they do not all fit into the Facione's [8] dispositions descriptions (in this work considered out of the framework dispositions, and categorized as others).

3 Methodology and Data Collection

This work reports some results of an exploratory study of qualitative nature aiming to explore and understand CT in professional life [5], specifically in relation to reasons, opinions and motivations of employers in relation to the importance, need and application of CT in the labor market.

The focus group technique [11] was used with a set of open-ended questions [11, 12]. The participants were professionals of business companies, organizations and employers from different areas, namely, Health and Tourism.

The research process was developed in four conceptual research steps [12, 13] – planning, composition, implementation, and data analysis. Planning involved the preparation of different documents required to organize the focus groups, such as the invitation letter, selection criteria, consent letter, thank you letter, as well as the design of the research instrument to data collection and scheduling. In the composition step, the selection of potential participants from different professional areas and sectors by convenience was made. In this study, two focus groups were organized, representing two different professional areas – Health and Tourism – respectively with 5 and 9 participants each area. Implementation was the third step, were two researchers (moderator and assistant) led the focus groups in the native language, Portuguese. All the participants who attended the focus groups provided written informed consent for participation in the study, for taping and/or videotaping the interviews, and for their subsequent transcription into text. Two focus groups were conducted in December 2016, each one having an average duration of one hundred and twenty minutes. The fourth step of data analysis is detailed below.

The focus group had five main questions, supporting the data analysis: Q1: What skills/dispositions are you looking for while employing university' graduates in your organization? Q2: What CT skills/dispositions do master your employees/colleagues/ workers? Q3: What CT skills/dispositions are of the most importance today? Q4: What CT skills/dispositions have to be improved/acquired today? Q5: What CT skills/dispositions will be needed in a near future in your organization?

The recorded data was then verbatim transcribed in the original language and each participant's speech was coded accordingly to the following system: sector_number-of-participant_professional-area (Data analysis). Briefly, a code was assigned to each sector represented [NGO (Non-Governmental Organization), PB (Public sector) and PR (Private sector)], followed by an anonymous code assigned to each participant (1 to n), that was followed by the identifier of the focus group (e.g., HEA – Health or TOU – Tourism). For this work, we use the P to indicate the Participant (interviewees), the HEA or TOU for the area, and the date of focus group.

All the "verbatim" transcriptions were directly used in content analysis [14]. The Facione's theoretical framework of CT skills and dispositions [8] was used as predetermined categories/ /codes for analysis, although other categories could emerge. The analysis and validation process took place in an interactive way. Namely, the data was coded and analyzed independently by two pairs of researchers; both identified the CT skills and dispositions. Later, the two teams of researchers compared their results and a final category was assigned.

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4 Results and Discussion

We present the main research findings of the CT concepts presented by the participants, its need, and practical uses in the workplace. We came up with an comparation and overall interpretation of CT by different professionals from Health and Tourism, reflecting on how the different CT skills and dispositions were expressed by the employers (participants), taking into account their own experiences and perceptions on the topic.

4.1 Critical Thinking Skills

According to Table 1, in both professional areas Health and Tourism all CT skills – defined by Facione's framework [8] – are identified. CT skills in Health have more mentions than in Tourism. In both areas, the number of total mentions were different.

Table 1. CT Skills by area

Skill	Health	Tourism
Interpretation	5	4
Analysis	5	1
Inference	3	3
Evaluation	8	1
Explanation	4	1
Self-regulation	6	4
Others (***out of the framework)	8	9
Total	39	23

In Fig. 3 we present the percentages of each skill in each area total (e.g. Interpretation: 5 in 39, 12.8% in Health and 4 in 23, 17.4% in Tourism) are presented.

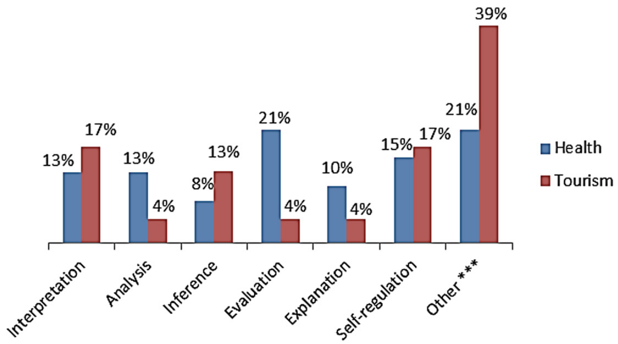

Fig. 3. Percentages of each skill in each area total

Within the two areas, CT skills “Self-Regulation” (10 out of 62, 16%) and “Other” (15 out of 62, 24%, out of the framework of Facione [8]) have more mentions.

In what concerns the CT skill “Interpretation”, clarity, good communication and the way speak to the patients were aspects that health professionals highlighted in the interview and how much this is relevant in their profession: “Communication is very important. We must ascertain if the patient understood all we said and taught (ex., during familiar treatment at home). Prescription is a crucial instrument for the treatment (so to know about the doses, the schedule, etc.). Communication, both written and oral, is very important. To know how to decode the patient language, make sure he/she understood [the instructions]” (P2_HEA, 19/12/2016).

In Tourism, “Interpretation” is also important, clarity, good communication as showed by the next quote: “If they have the ability to analyze a group right before they start the tour (…) 10 people in the maximum, they have to figure out what they want in the first few minutes, otherwise they will have problems, and they will not be able to pass the message”. (P4_TOU, 19/12/2016).

The “Analysis” skill is more often mentioned in Health (n = 5, 12.8%) comparatively with the Tourism (n = 1, 4.3%). In the Health area the capacity for synthesis, the ability to think differently, the ability to analyse medical exams, reports are basic allowances for the profession, for example: “Because it happens like this, a patient enters to show me the results for any exam, I take the report, and as I am aware of having only 15/20 min for the appointment, I look for what it is abnormal, because what is normal does not interest me. A less experienced doctor does not act like this. He may even loose an additional five minutes to transcribe everything [to the patient record].” And I ask “why are you transcribing all this? Which information do you retrieve/extract from that report? So, I this… that is synthesis skill” (P2_HEA, 19/12/2016).

In Tourism the importance of “Analysis” of the context and “Evaluation”, namely: “… interpret the signals that emerge from the context, I think these competencies are very important” (P9_TOU, 19/12/2016).

As regards to the “Inference” skill, health professionals referred that identification and secure elements are needed to draw reasonable hypothesis in order to draw logically valid or defensible conclusions, sample quote: “Therefore, at/in that moment my head has already passed all the information we acquired [during the medical appointment] and that allows recognizing if the situation is severe and, at the same time, take the action of referring him for other service…” (P1_HEA, 19/12/2016).

However, Tourism professionals referred to the design for conjecturing alternatives, for instance: “Here I also speak about the creation of some programs, as it was also said here, they have to be able to elaborate these programs knowing that people also want to have time to rest, want to have moments for shopping, want to have moments to be surprised, and the program has to contemplate all these tools, all those moments”. (P7_TOU, 19/12/2016).

Regarding “Evaluation” CT skill, in Health (n = 8, 20.5%) has more mentions then in Tourism (n = 1, 4.3%). The ability to assess the situation, the patient, and their statements is important so that health professionals can judge the credibility of the symptoms and the description that the patient refers; for example: “We must know, always/all the time, to know how to make analysis and synthesis simultaneously. Because, when a patient passes the door of the emergency room, we must perform an assessment at a glance, to evaluate if his condition is severe, if he needs this or that/not at all”. (P1_HEA, 19/12/2016).

The tourism professionals mentioned the importance of evaluating information to support decision-making. For instance: “Therefore, in order to have these high-performance teams and to reach these behavioral leadership standards, it is necessary to be able to collect, analyze and evaluate the information that basically supports our decisions to overcome the problems that we face (P9_TOU, 19/12/2016)”.

The “Explanation” skill had more mentions in Health (n = 4, 10.3%) than in Tourism (n = 1, 4.3%). For health professionals in their work it is important to develop communication skills and to be able to explain to patients the reason for that decision making, for example: “This cohort of competencies, technical, to screen the access [referring to long term vein access] and to communicate are truly important, to justify to the patient the decision-made, that we intend to increase the open vein lifetime, secure the access to the vein, etc. In brief, we need not only to have technical skills, the manual ability, but also the relational competencies, the communication and explanation skills in relation to the patient” (P3_HEA, 19/12/2016).

The “Self-regulation” CT skill, was mentioned in both areas. In Health, an emphasis on the critical and reflective ability over their professional practice was stressed. As an example: “We must perform/undertake a critical reflective analysis on what we are doing, namely on our clinical practice …” (P5_HEA, 19/12/2016).

In tourism, professionals mentioned the importance of reflecting, of having the critical ability, and the ability to modify their work strategy to achieve the desired results, for example: “… having a pedagogical and observational ability - so that they can do their own evaluation at any moment, of their own work and try to modify what they think that is necessary to perform well - and be versatile - if they are, they can perfectly see if their work is going as expected, or if they need to help a colleague or something like that” (P2_TOU, 19/12/2016).

4.2 Critical Thinking Dispositions

According to Table 2, both the Health and the Tourism areas all CT dispositions defined by Facione's framework [8] were identified. The CT disposition were reported with more or less the same number of references (23 in health and 29 in tourism). The CT disposition "Inquisitiveness" had slightly higher number of mentions (10 in 52, 19.2%) than the others CT dispositions in both areas.

Figure 4 shows the percentages of each disposition in relation to the total in each area (e.g. Inquisitiveness: 3 in 23, 1% in Health and 7 in 29, 24.1% in Tourism). In Health no "Other" dispositions were mentioned and "Analyticity" and "Self-confidence" had more mentions (n = 4, 17.4%). n Tourism more CT disposition mentions were counted for "Inquisitiveness" (n = 7, 24.7%).

Also in the Tourism area the professionals referred "Other" dispositions (n = 3, 10.3%) such as "Spirit of initiative", "Proactivity" and "Entrepreneurship", for instance: "In the company that I represent we have constant concern and we think that

Table 2. CT Dispositions by area

Disposition	Health	Tourism
Truth-seeking	3	3
Open-mindedness	3	3
Analyticity	4	5
Systematicity	3	2
Self-confidence	4	3
Inquisitiveness	3	7
Cognitive maturity	3	3
Other	0	3
Total	**23**	**29**

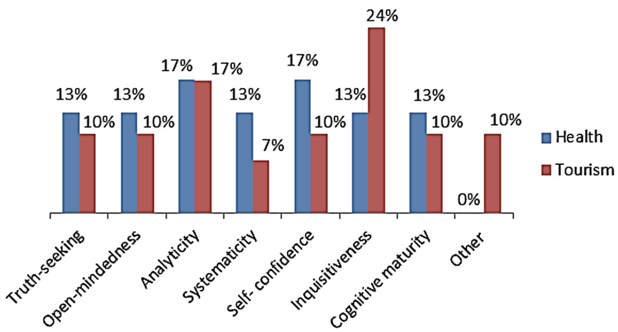

Fig. 4. Percentages of each disposition in each area total

this critical thinking is important, and we are concerned to hire people, above all, entrepreneurial, energetic, and active, but it is not only to have energy and be entrepreneur, it's about having it in a structured way". (P7_TOU, 19/12/2016).

For the CT "Truth-seeking" disposition, professionals in the Health area gave greater emphasis to seek help from their peers and to seek the best knowledge in a given context, for example: "Have the humility to search for another colleague that we have by our side to help us" (P5_HEA, 19/12/2016).

On the other hand, tourism professionals referred the need to be bold about asking questions, for example: "To have the capability and humility to question… to know how to question and how to criticize, to know how to see beyond the obvious is one of the things that I have always done and always valued in others (…) we must try and want to know how to question, and to be alert to see what lies behind anything that appears ahead" (P3_TOU, 19/12/2016).

Regarding, the CT "Open-mindedness" disposition, in the Health area there was a concern to be open to new learning and to other colleagues' views, for example: "Therefore, an openness to learning (…) to know how to listen the patient and get into his/her level (…) being intellectually open to learn". (P5_HEA, 19/12/2016).

The interviewed tourism professionals were more receptive to exchange and accept the different views of colleagues, namely: "The exchange of opinions, we must not just think that we are the only ones who know and the others should do as we say. It is also to allow employees to feel able to interact with all sectors of the company and collaborate" (P7_TOU, 19/12/2016).

In the CT dimension "Analyticity", was emphasized by Health professionals as the ability to assess situations and the ability to make immediate decisions, sample quote: "I don't know if this can serve as an example, this is a prompt decision, that is, evaluate the situation, see in that moment that we couldn't do medication there, no (…) This is a real situation. It was important to know in that moment that it was serious (…) So, it was a practical and verified decision, based on criteria and analysis." (P2_HEA, 19/12/2016).

In addition, the tourism professionals stressed the ability for problem solving as well as the preparation and knowledge for it, as in the example: "More than training individuals who have a static knowledge, it is important to prepare them for more complex tasks, prepare them for more complex environments, for uncertain contexts, and prepare them for problem solving, search for innovative solutions. All these are critical thinking skills, but I think it is… not only to have the knowledge, nor to have the ability, it is to have this attitude that I think should be more developed". (P9_TOU, 19/12/2016).

Concerning, the CT dimension "Systematicity", the professionals in Health area gave emphasis to the process of organization, systematization and analysis of priorities: "The time management, the organization of the work, the priorization. Thus, this is very important, because people may know a lot, but they can be lost in front of a patient and, instead of having the given 20 min (30 in private sector), they lose themselves in time and stay with other patients waiting. Thus, in a given situation, time management, make priorities, and the organization of the work, are essential." (P2_HEA, 19/12/2016).

In the Tourism area the ability to solve problems stood out: "A key thing for me is the problem-solving ability, and this problem-solving ability then has another component – it is often linked with experience, why? - It's because I've been through this in the past and I already know how to solve it". (P6_TOU, 19/12/2016).

For the "Self-confidence" CT dimension, the health professionals pointed out that leadership ability is essential to the profession: "The first important thing is that the professional feels able to exercise the profession. That creates solidity, in his performance, with that critical spirit to know the limits of what he knows and what he needs to do when he/she doesn't know. This is the first level of critical spirit that should remain along the whole career." (P1_HEA, 19/12/2016).

However, tourism professionals focused more on "Trust of ones reasoned judgments", for example: "Moreover, I think the issue of attitude is extremely important, it is important to develop intellectual integrity, because we often think one thing, but we do another - or by influence of others, or by other reasons – sometimes we think correctly but our actions lead us elsewhere". (P9_TOU, 16/12/2016).

For the "Inquisitiveness" CT dimension, both in health and tourism professionals declared the importance of constantly updating their training and learning focused on the job needs. For example, the following quote of a health professional: "We are always in continuous training. We cannot stop the training! And along the years, we learn to direct and guide our training. We feel what we need more. It's necessary to instill that: that people be in constant training". (P2_HEA, 19/12/2016).

In addition, for tourism the quote example: "From what I think that will be the demands of the future is the adaptability to change because the future will be this". (P6_TOU, 19/12/2016).

In the CT dimension "Cognitive maturity", health professionals revealed the importance to know how to intervene in a specific context and to seek for and to consider different opinions of their peers, as in this example: "When he faces a patient he also faces with himself… he has to develop the critical thinking in this sense: neither put him in the situation of incapable, nor put himself in the situation of fully capable. To deal with a situation, to call a colleague to see, whatever the moment in life we are in. It only benefits those who do it, and obviously those who receive it". (P1_HEA, 19/12/2016).

On the other hand, the interviewed professionals in Tourism strengthened the ability to adapt to the practical situations they will have to deal with. For instance, like in this sample quote: "I think that more than transmitting a static knowledge, it is important to transmit knowledge with applicability. Last week we had some interviews for a training program that we are developing, the students were technically excellent, but this question of applicability was lacking (…) for all, the technical questions were responded perfectly, but at the time when it was needed to transfer this knowledge to practical situations of the company, it was more difficult for them". (P9_TOU, 19/12/2016).

5 Reflections and Future Work

In summary, in the focus groups led, the Health area there had greater number of mentions in the CT skills than Tourism area; in turn, the Tourism area the latter presenting higher number of mentions of CT dispositions. In the Health area, the more mentioned CT were Evaluation, Others (out of the Facione's framework [8] such as, Interpersonal Skills, Establishment of priorities and Communication skills) and Self-regulation; in the Tourism area the out of the framework CT skill stood out. In Health area, all the dispositions got more or less the same number of mentions. However, in the Tourism area Inquisitiveness and Analyticity highlighted. Finally, CT skills and CT dispositions examples were different in each of these two professional areas (e.g. [2, 6, 9–11]).

The Health professionals who were interviewed for this work emphasized their professional practice and their critical thinking in the several dimensions related with the well-being and the clinical state of a specific patient (namely in the processes involved: diagnosis, treatment, prevention). This is in line with Huang et al. [5] that stated: "Critical thinking is a prerequisite for effective judgment, and its absence in the clinical realm can result in delayed or missed diagnoses, cognitive errors, and mismanagement. The centrality of critical thinking is clearly reflected in competency frameworks across the health professions".

The Tourism professionals interviewed for this work referred interpersonal skills, communication, and creativity (e.g. [4]) as other CT skills. The Tourism professionals mentioned that critical thinking is essential for their professional development and enables them to develop a set of important skills for effective management, service delivery, and the provision of products, that allow customer satisfaction. As Stone et al. [6] conclude, "in order for future tourism professionals to be successful, they will need to be creative, innovative, and entrepreneurial – all of which require the ability to think critically".

As future research, we aim to pursue the connection between the needs of the labor market and the training of the graduates for both CT skills and CT dispositions needed for their work practice, and in both areas: Health (e.g. [5, 9]) and Tourism (e.g. [6]). As expressed by Morrissey et al. [15]: "The goal is to produce the workforce of the future—physicians who have the skills to innovate and improve health. This strategy shifts the focus from self-reliance, self-preservation, and passivity to team building and collaboration".

The goal of the present work was to report the Erasmus+ project results that are the CT skills and dispositions foreseen by the employers that participated in the focus groups of Health and Tourism. The North and Northeastern professionals interviewed gave us only a first glimpse of their opinions, which do not reflect whole professional's opinions. In order to consolidate these results, larger number of participants, in focus group interviews and different kind of professional participants from each area are needed. Hence, we acknowledge these study limitations.

As already stated, in order to reinforce this first approach to the views of employers in the Health and Tourism areas in the future, some follow-up studies in each area with different and bigger spectrum of professionals is needed. In addition, some questions arise in order to get a good picture of CT in professional careers: what types of CT skills and CT dispositions are common (or not)? Are the CT skills and CT dispositions mentioned (or not) in this study the same (or not) for other professionals in these areas (or in other areas)? There is still work to do.

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Perceptions of Portuguese University Teachers About Critical Thinking Educational Practices

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Abstract. Promoting students' Critical Thinking (CT) in Higher Education Institutions (HEI) has been an essential and challenging goal in the 21st century. This exploratory research study attempted to characterize how CT is being fostered in Portuguese HEI. Semi-structured interviews were carried-out with 5 university teachers from different domains, focusing several topics: CT notion, CT aims, CT approach, interventions, teaching strategies, learning materials, assessment methods, challenges and barriers. Results highlighted the undervalue of CT dispositions by university teachers, the lack of clarity regarding the design principles and criteria behind effective CT instruction and assessment, and the need to change institutional culture and conditions towards the support of CT educational practices – this will also enable the long-term integration of CT across the curricula and the transferability of skills and dispositions to other contexts. In general, teachers agreed on the importance to be explicit and clear in their CT teaching practice, and on the use of authentic situations, dialogue and active learning strategies for the effective development of students' CT.

Keywords: Critical Thinking · Skills · Dispositions · Higher Education Institutions · Learning · Assessment

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1 Introduction

The aim of this paper is to contribute to the understanding on how Critical Thinking (CT) is being fostered in Portuguese Higher Education Institutions (HEI), taking into account the current educational interventions carried-out by different university teachers. This study was conducted in the scope of a broader project, involving 9 European countries, intended to propose guidelines for quality in CT education in HEI (project CRITHINKEDU – Critical Thinking across the European Higher Education Curricula). In order to get a better insight of the instructional practices used to promote CT in Portuguese HEI, 5 university teachers (hereafter, "teachers") from different scientific domains and disciplines, e.g., Biomedical Sciences, STEM, Social Sciences, were interviewed. Besides the examination of CT aims, the overall approach to CT, the type of intervention, the teaching strategies, the learning materials, and the learning assessment, interviews intended also to identify the challenges and barriers found by teachers in the adoption and implementation of CT educational practices.

2 Background

There are many conceptions of CT, in different domains (mainly in philosophy, psychology, and didactics) related with diverse research concerns (e.g., [1, 2]). In this study, we assume the concept of CT presented by Facione in the Delphi report [3], whose definition represents a consensus statement from a panel of experts regarding CT and the ideal critical thinker. Facione's definition points out at a set of skills involved in CT, but it also focuses the inquiry nature of CT and its potential for personal and social life: "We understand critical thinking to be purposeful, self-regulatory judgment which results in interpretation, analysis, evaluation, and inference, as well as explanation of the evidential, conceptual, methodological, criteriological, or contextual considerations upon which that judgment is based. CT is essential as a tool of inquiry. As such, CT is a liberating force in education and a powerful resource in one's personal and civic life. While not synonymous with good thinking, CT is a pervasive and self-rectifying human phenomenon" [3, p. 2].

In this conception, CT is also assumed as a set of dispositions: "The ideal critical thinker is habitually inquisitive, well-informed, trustful of reason, open-minded, flexible, fair-minded in evaluation, honest in facing personal biases, prudent in making judgments, willing to reconsider, clear about issues, orderly in complex matters, diligent in seeking relevant information, reasonable in the selection of criteria, focused in inquiry, and persistent in seeking results which are as precise as the subject and the circumstances of inquiry permit" [3, p. 2].

In the literature, it is broadly acknowledged that CT is expressed not only by cognitive elements, but also by propensity factors, like attitudes and dispositions [4–6], thus promoting the development of the individual as a person. It's also common to assume CT as intellectual attitudes and habits of mind [7], entailing a reflective basis for decision making and judgement, as well as a set of affective states and virtues – also named as "critical spirit" [8] or "spirit of inquiry" [9]. Still, a critical thinker is seen as someone who is able not only to start or engage in a thoughtful task, but also to be persistent and/or willing to do so [6]. Some authors strengthen also a sociocultural dimension of CT, in pair with personal skills and dispositions. In this sense, CT includes the ability "to participate critically in the communities and social practices of which a person is a member" [10, p. 375, 11]. Also Facione connected CT to one's role in society, as he concludes the definition of CT highlighted above saying that educating good thinkers "combines developing CT skills with nurturing those dispositions which consistently yield useful insights and which are the basis of a rational and democratic society" [3, p. 2]. Moving from the traditional sense of CT, Barnett [12] uses the term "criticality" in order to incorporate the individual's wider identity and participation/action in the world. In brief, criticality is presented by Barnett as having its scope in three domains: "formal knowledge, the self, and the world" [13, p. 63], which entail critical reason (thinking), critical self-reflection (being) and critical action (acting).

Across the different movements in CT education and research, it's nowadays consensual that CT is an essential skill for acquiring knowledge, for personal domain and for citizenship. Considering the labor market, CT is a major asset for graduates' employability and successful integration in society [14].

Educators have an important role in promoting CT skills, dispositions and attitudes in class. In respect to HEI, some researchers reinforce the need of wider models of CT, incorporating also concerns as: "How critical thinking is represented in debates about critical pedagogy, the role of education in leading to individual and collective socio-political activism, the place of critical thinking in educating for citizenship, the role of critical thinking in relation to creativity" [2, p. 43].

Efforts should focus on the development and daily practice of CT, across disciplines and the curriculum, and this implies a strategic role of academic leaders in providing policy and support to promote CT education as part of the organizational culture – driving institutional change by quality standards, pedagogical models and practices.

The extent to how critical thinking can and should be taught has called researchers' attention since the early and mid-1980s [15–19]. The recognition of CT development by scholars/educators, employers and society in general has stimulated the re-design of general and domain-specific courses, the reviewing of instructional methods, and the search for the most effective interventions at improving students' CT skills and dispositions. There are many well-developed models intended to educate for critical thinking, as Davies points out [2, p. 43]: some models advanced along Bloom's taxonomy of educational objectives [20]; others developed in relation to cognitive decision-making [5]; and some widespread models followed the APA Delphi and the Paul-Elder's proposals [3, 21, 22].

Teaching CT is a challenging matter. Some researchers argue that CT can only be taught in the context of a specific domain and agree on the importance of background and/or domain-specific knowledge as a precondition to CT development [23, 24]. Some support that CT transfer across domains may only occur if students are provided with opportunities to practice these skills in a variety of domains and if they are explicitly taught to transfer [25]. Evidence suggests that academics' and employers' conceptualization of generic attributes and professional skills commonly subsumed in CT are influenced by the domain of the discipline in which they are taught and/or practiced

[26–28]. In particular, this is because valid evidence, arguments, and standards tend to vary across domains, depending upon the epistemological context [29].

Assuming the teachability of CT, researchers have been proposing different instructional approaches. According to the Delphi panel experts [3], CT cannot be considered as a body of knowledge to be delivered to students as one more school subject along with others; instead, CT can occur in programs with discipline-specific content or in programs that rely on the events of everyday life as the basis for developing one's CT. The question whereas CT should be a separated course or should be embedded in standard courses divides some authors. Ennis [25] categorized the various approaches to CT instruction as general, infusion, immersion, and mixed: in the general approach, CT abilities and dispositions are taught separately from the content of the subject matter; in the infusion approach, CT is integrated in subject-matter instruction and general principles of CT are made explicit; in the immersion approach, CT is also integrated in subject matter instruction, but general CT principles and procedures are not made explicit to students; in the mixed approach, there is a combination of the general approach with either the infusion or the immersion approach, and CT is taught as an independent track within a specific subject.

Teaching strategies to promote students' CT have always been in the minds of researchers. In a comprehensive vision for a HE program incorporating CT across the curriculum, Ennis [30] recommends two basic teaching methods, both helpful, depending on the situation, the subject, the students, and the teacher: Lecture-Discussion Teaching (LDT) and Problem-Based Learning (PBL). LDT, the most common approach to college teaching in Ennis' proposal, is described as a lecture presenting one or more aspects of the subject matter, followed by a discussion; PBL is more suitable for dealing with issues that require investigating, developing, testing, and discussing of hypotheses or solutions and possible alternatives. In addition, Ennis suggests a selection of twenty-one strategies and tactics for teaching CT (presented in [31]). According to Niu, Behar-Horenstein and Garvar [32], and to Pithers and Soden [33], PBL is one of the most widely-used learning approaches in CT instruction because it is motivating, challenging and enjoyable.

In the literature on teaching strategies, there are either proposals focused in some aspects of CT, or general guidelines intended to the overall fostering of CT in students. Supported in his own experience and many researchers, Ennis [30] endorses the general teaching guideline "We learn what we use", and he recommends two basic and complementary teaching practices: to make CT principles explicit when they are used or relevant; and to teach for transfer, that is, to promote transferring the application of CT dispositions, abilities, criteria, and principles at a variety of new examples in new contexts. Several CT researchers recommend a collaborative or cooperative approach to instruction [3, 18, 34–37]. These approaches highlight the potential for cognitive, attitudinal, and interpersonal improvements when students interact with one another, in peer activities or in working groups. To sum up, literature concerning the promotion of CT in education discusses interventions ranging from self-study, mentoring, dialogue, essays' or arguments' writing, peer-assessment, to experiment and authentic situations; learning strategies and methods more discussed are lecture discussions, argumentation, role-playing, inquiry, peer-review, peer-observation, self-evaluation, conceptual mapping, cooperative learning, case studies and problem solving [38].

Teachers' decision about which learning strategies to implement depends strongly in the analysis of the effectiveness of CT instruction. Despite the large number of researches about teaching CT in HEI, there is little agreement regarding the conditions under which instruction could result in greater CT outcomes [34, 39–43]. In their review of research on CT instruction effectiveness, Tiruneh, Verburgh and Elen [41] conclude that it is influenced by conditions in the instructional environment comprising the instructional variables (teaching strategies and CT instructional approaches), and to some extent by student-related variables (year level and prior academic performance). They found evidences of a shift towards embedding CT instruction within academic disciplines, but they concluded that there wasn't enough evidence to support effectiveness of particular instructional strategies in fostering acquisition and transfer of CT skills.

Strongly imbricated in the evaluation of learning methods to improve CT, it is still more challenging the assessment of (progresses) in acquisition of CT by students. In general, researchers argue that assessment must be addressed early and continuously, with prompt feedback to students, and it must be done having diagnostic, formative and summative purposes, at different moments of learning interventions, helping educators to learn about students' accomplishments and to plan future interventions. There are many tests to assess students' CT, including some well-established, and with regular actualizations, as the Watson-Glaser Critical Thinking Appraisal [44], the California Critical Thinking Skills Test [45], the Cornell Critical Thinking Tests (CCTT), levels X and Z [46, 47], the Halpern Critical Thinking Assessment [48], and the Collegiate Learning Assessment [49]. The literature refers mainly to these tests or their adaptations to other languages, but some new proposals are arising and being widespread (e.g., [50–52]). The numerous existing tests vary widely in the kind of measures, formats (e.g., standardized or not, open- or closed-ended questions, multiple-choice questions or writing essays or arguments), purposes, tasks demanded, time to perform the tests, students' age they are addressed to, and dimensions of CT on focus (some assess general skills or abilities, and others are specific to knowledge domain or some aspects of CT).

3 Methodology and Data Collection

We carried-out semi-structured interviews with five Portuguese university teachers (Table 1), all of them with relevant publications on CT education and committed to the promotion of CT in their own classes. Interviewed teachers (IT) were asked to describe their perceptions about CT teaching, namely: how can CT be promoted in HE; what type of interventions, teaching strategies, and evaluation methods that are being used to promote CT; and what challenges and limitations teachers have to face nowadays in their CT instruction.

The interviews were carried-out individually, face-to-face or online (via Skype), and lasted about 64 min each. The teachers' selection for the interviews was based on their previous experience in CT education and field categorization; they came from different domains in order to obtain an integrated view on CT instruction at the university level.

Table 1. Distribution of the interviewed teachers.

Domain	Interviewed teachers (IT)
Engineering/STEM	2
Social science	2
Biomedical sciences	1
Total	5

The interviews guide was based on interview protocol of Paul, Elder and Bartell [53] about teacher preparation for instruction in CT. The interviews were organized in 8 open-ended questions: (1) How would you explain to me your concept/idea of CT?; (2) What particular aspects of CT do you believe are most important for your students to develop? And why? (3) Could you describe the practices (approaches/strategies/ interventions) that you use in your classroom to foster CT? Please, give an example; (4) Which learning materials do you use to promote CT in your classroom?; (5) Do you assess CT abilities of your students? And how?; (6) What challenges do you experience when developing CT in your students? How do you try to address them?; and (7) Are there any institutional barriers that limit the promotion of CT education?

The interviews, conducted in the mother tongue (Portuguese) were audio-recorded and transcribed. Interview contents were subjected to qualitative content analysis [54]. Content analysis matrixes were organized into dimensions and categories for the analysis. We conducted the analyses process for all teachers' responses, question-by-question, following 4 stages:

1. Decontextualization (break down the text into smaller meaning units): researchers got familiarized with the data and read through the transcript to obtain the sense of the whole, before it could be broken down into smaller meaning units. By "meaning units" we refer to the constellation of sentences or paragraphs containing aspects related to each other, covering different dimensions of CT addressed in the interview.
2. Recontextualization: after the meaning units were identified in the transcript, we confirmed whether all aspects of the content had been covered.
3. Coding in pre-established categories: teachers' responses were coded into the main categories and subcategories defined previously. The rubric used for the analysis of the literature reviewed served this goal, although two more dimensions were added: CT instruction in teachers' training and institutional barriers. This process of responses categorization was based through deductive reasoning and was carefully reviewed.
4. Description of the results and quotes: results were illustrated with quotes from interviews in order to provide readers with a clear idea about how university teachers promote CT in their classes.

The script of the semi-structured interviews and the content analysis matrixes were previously built based on systematic literature' reviews about CT and educational interventions, namely [3, 25, 30, 34, 39, 41]. The conception and validity of content analysis matrixes were conducted by an iterative review process between two teams of the project (the Spanish and the Belgian partners). Following the same matrixes, international partners carried out the content analysis of the interviews that they had conducted at national level.

In the content analysis of Portuguese interviews, we applied a cyclical process of improvement, synthesis, and reflection. In a first moment, one researcher created the content analysis matrixes. After this, another researcher independently validated or suggested changes to these content analysis matrixes. They were discussed later until both researchers reached an agreement. Lastly, after translation to English when necessary, the final version of the content analysis matrixes was validated by all the research partners.

4 Results and Discussion

The results are organized in eight subsections, each one representing the different questions asked to the participant teachers. Each subsection has a table containing the dimensions, categories of the analysis and the number of teachers who mentioned each category. This information is complemented with sample quotes from teachers.

4.1 Question 1 – CT Notion

All interviewed teachers (n = 5) define CT accordingly the Facione definition [3]. Teachers conceptualize CT as a "set of skills and/or dispositions". For example: "For me CT is to think better … is to develop some mental processes that allow us to raise the standard, the quality level of our thinking … I understand it more by achieving a mental process that allows me to make better decisions, that allows me to solve problems, in a way that takes into account the perspectives of all, the various arguments, after a careful analysis and a comparison/analysis of the evidence, etc. Therefore, if this also requires working on self-confidence, curiosity, etc." (T2, 09/06/2017).

4.2 Question 2 – CT Aims

In the subsection about the CT aims that teachers consider more important (Table 2), there are more mentions to skills (21 quotations) than to dispositions (only 4 quotations). The interviewees indicated several CT skills, but "Analysis" (n = 4) was the one more frequently mentioned. For example: "They [students] need to be able to consider different options and especially not to follow a checklist, not to automate the way of thinking and therefore to be able to construct, analyze a situation, build with the previous knowledge that they have in order to reach new approaches, new proposals" (T5, 16/06/2017).

Table 2. Analysis of interviews: CT aims.

Dimensions	Categories	IT (N = 5)
Skills	Analysis	4
	Self-regulation	3
	Evaluation	2
	Explanation	2
	Inference	2
	Interpretation	1
	Others (not in [3]):	
	Argumentation and Decision making	2
	Synthesis	2
	Adaptability	1
	Group work and creative thinking	1
	Questioning	1
Dispositions	Self-confidence	2
	Inquisitiveness	1
	Systematicity	1
	Analyticity	0
	Cognitive maturity	0
	Open-mindedness	0
	Truth-seeking	0
	Other (not in [3]):	
	Motivation as a general disposition	1

"Self-Regulation" was also frequently mentioned (n = 3), as in this sample quote: "They [students] have to become aware that there are certain mental mechanisms, and that if we apply them we will come to a better way of thinking. So yes. It would also be important, in this case, that self-consciousness of these processes" (T2, 09/06/2017).

Other CT skills were mentioned, but less often: "Interpretation" (n = 1), "Inquisitiveness" (n = 1), "Inference" (n = 2), "Evaluation" (n = 2), and "Explanation" (n = 2).

Interviewees have mentioned CT skills not included in Facione categories [3], such as: "Questioning" (n = 1), "Synthesis" (n = 2), "Group work and creative thinking" (n = 1), "Adaptability" (n = 1) and "Argumentation and Decision making" (n = 2). One example referring to "Argumentation": "Is not to say 'I am for or against' - this is not CT. CT is to argue with arguments that are valid, depending on the knowledge that we have on that moment, on that context (…) Therefore, they have to be valid and reasoned arguments. What I try to develop in students is that they are able to argue and take a position" (T4, 14/06/2017).

Regarding CT dispositions, "Self-confidence" (n = 2) was mentioned in these terms: "And here I focus a lot on what is Veterinary Medicine and the practical application of theoretical knowledge, also needing to have some degree of confidence to be able to say "this is not what I see, the explanation doesn't fit and I want a different explanation or propose other one" (T5, 16/06/2017).

One interviewee has also mentioned a general disposition that was not in [3], namely "Motivation" (n = 1): "And it is this disposition that I also need to have to react to these situations. Because it's not a purely cognitive competency, it is also motivational in nature" (T4, 14/06/2017).

4.3 Question 3 – Educational Practices to Foster CT

As shown on Table 3, when asked about their educational practices to promote students' CT, teachers have only referred to "Immersion" (n = 1) and "Infusion" as the overall approach, as in this quote: "So, if the questioning has no didactic intentionality, it is an inert questioning. That is, it has no direct educational results to develop CT. Well, the CT, as you know, has to be developed intentionally. No one develops indirectly, or because I did another activity. Both the questioning and the argumentation at the service of the CT has to be done intentionally" (T3, 14/06/2017).

Table 3. Analysis of interviews: practices to foster CT.

Dimensions	Categories	IT (N = 5)
Overall approach [25]	Infusion	4
	Immersion	1
	General	0
	Mixed	0
Specific type of interventions [34]	Authentic situations	5
	Dialogue	5
	Self study	5
	Mentoring	0
Teaching strategies	Lecture discussions (argumentation)	6
	Problem solving (inquiry)	4
	Questioning	3
	Group work	2
	Role-playing	2
	Self and peer assessment	2
	Context-based learning	1
	Cooperative learning	1
	Flipped classroom	1
	Online peer review	1

Regarding the type of interventions, teachers mentioned:

– "Self-study" (n = 5), sample quote: "Then, in the classroom, alone, individually, they analyze a text following the FRISCO grid with one or two tasks that are not requested in the FRISCO grid" (T2, 09/06/2017).
– "Dialogue" (n = 5), for example: "And then, they'll have to discuss and argue with me if they're thinking that the information they will get from that kind of answer is important or not to get to the final evaluation" (T5, 16/06/2017).

– And “Authentic situations” (n = 5), for example: “I have had such a simple experience, for example, asking students who will be future teachers of the first and second level, to elaborate potential questions that could be asked to the children” (T4, 14/06/2017).

It is worth noting that no teacher explicitly referred to adopt “Mentoring”.

Some teaching strategies usually not highlighted in the literature were mentioned by teachers, such as: “Self and peer assessment” (n = 2), “Group work” (n = 2), “Context-based learning” (n = 1), “Questioning” (n = 3), “Online peer review” (n = 1), “Cooperative Learning” (n = 1), and “Flipped classroom” (n = 1).

4.4 Question 4 – Learning Materials

All interviewed teachers have mentioned several tasks and learning materials intended for HEI students to develop CT (n = 5) (Table 4). All interviews focused the “Problem situations or cases” (n = 5), for example: “We created scenarios (problem situations) in which they have to solve them to be able to develop those skills that are in deficit (…) situations are created and have to be related with the topics of the curricular unit (…) Basically they are pedagogical scenarios, case studies, situations that are being created and adapted. I also look for news from other contexts. The videos are also something that interests me a lot. And then I also ask them to bring things that they can discuss” (T4, 14/06/2017).

Table 4. Analysis of interviews: learning materials (including features of tasks).

Categories	IT (N = 5)
Tasks intended for university students to develop CT and learning materials used for this goal (e.g., video, lecture notes)	*(5)*
Problem situations/cases of a business company	5
Articles/papers/videos/presentations	3
Questions	3
Role-play	3
Conceptual maps	2
Group discussion using a problem situation/case to solve or take a decision	2
Self and peer-assessment using a rubric in an online tool	2
Written reports and oral presentation recordings	2
Diagnosis algorithms	1
Hypothetical situations/cases	1
Online peer review with the analysis of a written document, using an appropriate template, the FRISCO grid and the SWOT framework	1
Paper sheets	1
Socrative mobile app	1
Tasks intended for university students to transfer CT to their target and learning material used for this goal (e.g., video, lecture notes)	*(2)*

(*continued*)

Table 4. (*continued*)

Categories	IT (N = 5)
Questions; small cards with generic questions	2
ArguQuest digital tool	1
Problem situations/cases	1

In contrast, few teachers (n = 2) mentioned specific tasks and learning materials for HEI students to transfer CT.

4.5 Question 5 – Assessment Methods

In this subsection, teachers both adopt formative and summative assessment (Table 5). Almost all interviewees (n = 4) said they use the formative assessment with feedback (n = 4), sample quote: "We strive to give feedback during the process, to be formative rather than summative (…) I analyze the questions almost as if they were answers or interviews from the students, and I can extract meanings from the questions that often are not possible in a practical and viable way. (…) I can through a taxonomic system categorize these questions in a quick and simple way (…) That is, I can follow, through the pattern of questioning, the quality of the questions, the role of the questions, their nature, the elements that allow me to evaluate these questions and, therefore, indirectly the CT" (T3, 14/06/2017).

Table 5. Analysis of interviews: assessment methods.

Categories	IT (N = 5)
Formative assessment with feedback	4
Summative assessment: grading of the final written assignment	2
Formative assessment: teacher' feedback during and after each activity; self and peer-assessment after each activity	1
Formative assessment with pre and post-test	1
Formative assessment with Cornell Critical Thinking Test (CCTT)	1
Summative assessment with grading and feedback of the written peer reviewed documents	1
Summative assessment with grading of the type of students' questions resulting from the group work discussions	1

Interviewees mentioned assessment instruments in general, for the formative and summative evaluation of activities that they carry out in their classes.

4.6 Question 6 – CT Challenges

There are several CT challenges mentioned by teachers (Table 6), which may be distributed in four categories (classroom settings and organization, teachers and student's mindset, CT skills assessment, and other categories).

Table 6. Analysis of interviews: CT challenges.

Categories	IT (N = 5)
Teachers' and students' mindset	5
Time, size and duration of classes	4
CT assessment (both summative and formative)	1
CT in a digital world	1
CT skills assessment (inadequacy of the current formal tests, such as the CCTT)	1
CT skills assessment (transfer)	1
Difficulty to implement some activities	1
Students' engagement with CT	1
Support	1
Teachers' commitment	1
Teachers' resistance in being observed	1
Technical bugs	1

The main challenges teachers pointed out was "Teachers' and students' mindset" (n = 5), for example: "The main challenge to develop CT is this inertia. Critical thinking requires energy, and this energy is not much sought in our educational system and process. (…) So one of the main challenges is that the development of CT gives teachers work, but also gives students work, and this, to take students from inertia, to pull them to question, to argue, etc. (…) The very barrier is the teacher, because a teacher who is not trained or sensitized to CT, he/she will hardly develop it" (T3, 14/06/2017).

And also the "Time, Size and duration of classes", as in this example: "And then the number of contact hours that is relatively small for such activities in a theoretical class – I should have enough hours that allow me to meet the schedule or course syllabus" (T5, 16/06/2017).

4.7 Question 7 – Institutional Barriers

Interviewees have pointed three institutional barriers (Table 7). All teachers mentioned as an institutional barrier the lack of recognition of "CT as institutional priority" (n = 5), example: "and then, effectively, have institutional support. That the whole institution, especially the top management and leaders, recognize this work (because I think teachers also like to be recognized), that they recognize that it's valid and it will take the university to another level of quality teaching. And that, if they feel it, and a kind of requirement … I see in the evaluations, in the RADE (the institutional regulation for teachers' performance evaluation), which says: 'integrates innovative methods'. But, what are innovative methods? How they evaluate them? Who evaluates? (…) by the evaluation system of teachers, this does not seem to be valued, because it's only one more insignificant element…" (T2, 09/06/2017).

Table 7. Analysis of interviews: institutional barriers for promoting CT.

Categories	IT (N = 5)
CT as institutional priority	5
Institutional culture	3
Lack of university-business cooperation in the curricula	1

The interviewees mentioned the institutional culture as a barrier to promote the development of CT skills in university and among teachers and students (n = 3): "Because what I have seen, with almost 38 years of service and teaching, is that these skills have been lost. Because I also think that the university shapes the students' thinking more than deforms it. It deforms in the sense that people have divergent thinking, but they don't. People are trained to have convergent thinking, to think all in the same way. Does this also apply to teachers? Yes. Because we also value those who think like us" (T4, 14/06/2017).

Still, one teacher exposed the lack of University-Business cooperation in the curricula.

5 Conclusions

All teachers interviewed adopted the definition/concept of CT presented in the Delphi report [3], but they referred mainly to skills, and scarcely mentioned dispositions. In future work it will be important to understand why the CT dispositions are less referred.

The interviewees pointed out immersion and infusion as the most used approaches to integrate CT in their daily classroom practices. It is important in future work to ascertain and understand whether for teachers in Higher Education the concept of CT is clear in their professional practice and how this is reflected in the instructional design of their courses. Also, it is important to understand how the institutional context influences the adoption of teachers' pedagogical approaches to promote CT and if teachers have the necessary training to integrate them in their practice. As Abrami and colleagues stated [34], a crucial factor for adoption of strategies that promote CT skills and dispositions is related to experience, training and background on CT. In this way, for practical implications of this work, teachers' training is recommended as well as all the support needed to enhance the pedagogical practices promoting students' CT.

Except the Mentoring, all other types of interventions are adopted by the interviewed teachers. Here, the use of Authentic Situations (e.g., real-world scenarios and case studies) and Dialogue seem to be effective ways to foster CT development in higher education students. Considering the various types of teaching strategies, the most common among the teachers interviewed is problem-solving. Regarding the learning materials that teachers use for the development of critical thinking, and although their wide variety, only two teachers referred to use materials and/or resources which promote the transfer of critical thinking in different contexts. In future work, it is recommended to deeper the analysis on this transferability issue.

Regarding CT assessment, all teachers adopt formative and summative evaluation strategies and/or tools, and there is a greater incidence in the formative evaluation type with continuous feedback. However, there is a lack of explanation and clarity on how teachers apply and practice it. In future work, it is recommended to verify if teachers have enough knowledge about how to assess CT development of their students, as well as to better understand in what extent these formative strategies can be integrated within the teaching practice. Also, and attending that the educational interventions reported in this study are short-term, will be important to analyze how CT can be fostered across the curricula, in a more systematic way, attending to the longitudinal and mid-term setting that better enable the development of CT dispositions.

The teachers interviewed emphasize, as for the challenges in CT education, the need to change the students and teachers' mindset (change of the institutional culture). Also, other challenges and difficulties are mentioned, namely: the lack of institutional support in the promotion of CT; difficulty in implementing activities due to the size of the class (high number of students), organizational conditions (class length), which are in line with [55].

6 Limitations

The overall results obtained in interviews with Portuguese teachers at HEI are in general coherent with findings in the literature. Nevertheless, there are some limitations that demand future work: the sample size (few number of interviewees), and representativeness (limitation of the scientific domains). Notwithstanding, this study characterize some of the current CT educational practices that has been adopted in different Portuguese universities. Future studies should include more university teachers from different domains and the comparison of their perceptions with the empirical studies already reported in the literature regarding the CT educational interventions within the Portuguese HEI landscape [56].

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Digital Tools in S&T Learning

Digital Resources in Science, Mathematics and Technology Teaching – How to Convert Them into Tools to Learn

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Abstract. This paper deals with the problem of why many teachers take up little educational benefit from digital resources, despite their potential to help create learning environments with greater student engagement and stimulating intellectual challenges. A systematization of the main factors identified in the literature is made. Starting from a framework based on the idea of conceiving any educational resource as an artefact that can be used as a tool, and extending the concept of instrumental orchestration, guidelines are proposed for using digital resources as epistemic tools to learn and a research program to be implemented.

Keywords: Digital resource · Science and technology · Epistemic tool · Learning classroom · Artefacts orchestration

1 Why Many Teachers Take up Little Educational Benefit from Digital Resources?

There is a great diversity of educational resources available to learn Science, Mathematics and Technology (SMT) [1]. However, the SMT teacher does not always take advantage from its educational potential [2, 38]. Although there is extensive work on the use of educational resources in SMT [3, 4], its use in SMT teaching practices has, among others, two types of gaps that need to be better understood and solutions to be found:

(1) The educational benefit of the digital resources to learning is not taken advantage of, in many situations, because teachers consider them less attractive [2], or because teachers do not recognize them to have a central role in the learning that offers students a space of autonomy and productive engagement [2, 5, 6].

(2) The use of digital resources in SMT teaching practices lacks a theoretical and practical framework that supports this process in order to promote improvements in learning. It is necessary to extend the studies on "epistemic tools" (tools for creating ideas and building knowledge [4] in professional contexts, including that of scientific research), where they are most studied, to the formal teaching context of SMT [7].

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These two gaps can have a common origin: SMT teaching is marked by pedagogical approaches (even those based on constructivist perspectives of learning) centered on established knowledge rather than on open epistemic practice that prepare students to deal with what is not yet known [7, 18].

2 Factors Which Explain the Little Educational Benefit for S and T Learning When Digital Resources Are Used

Design [20] plays a crucial role to take advantage of digital resources. Drijvers [20] gives account of three interrelated design levels: (i) the design of the digital technology; (ii) the design of corresponding tasks and activities; and (iii) the design of lessons and teaching. In addition, literature has drawn attention to factors linked to students' knowledge and skills [21, 23].

2.1 Factors Related to the Quality of Digital Resources

A first step, relevant in the use of digital tools in the learning of SMT, is that design enhances the technical mastery of using digital resources for solving mathematical (and sciences) tasks, and the conceptual understanding of the scientific concepts involved [20]. Therefore, digital resources characteristics and affordances should be adequate to the learning situation in which they are incorporated [20]. However, pedagogical and didactic principles should guide design, rather than the digital resources limitations or properties [20].

In [34] several criteria were proposed to evaluate the quality of digital resources. They concluded that not all digital resources have the necessary qualities. Therefore, the first step is to choose the digital resources that maximize the possibilities of obtaining educational benefit (scientific, technical and didactic qualities, and quality of interactivity and usability) [34].

2.2 Factors Related to Students' Expectations and Skills

The use of digital resources by students requires not only that they master the technology, but mainly a greater knowledge of the contents involved in the task (the concepts, their relations and properties) [23]. Another important aspect for students to be successful in the use of digital resources is the degree of adequacy of students' digital skills to the degree of requirement of the resource itself [21].

2.3 Factors Related to the Exploration Guide

The guidance degree of the task is a matter of debate [24, 25]. There is, however, some consensus that a certain guidance degree is necessary and is more effective for student learning [26–29, 31]. Research has shown that this subject is complex and has to be adapted to students' previous knowledge and to their own experience [30].

2.4 Factors Related to Teacher's Mediation

The use of digital resources in an educational context presupposes that this integration is done in a flexible and coherent way. This is part of the teacher role, as well as promoting students' motivation and engagement in tasks [20]. How they take place in teaching practices essentially depends on the actions and beliefs of teachers [15, 38].

Teaching with technology is different and the role of the teacher is widely recognized in promoting learning situations with digital resources with educational benefit. These changes require the engagement of teachers in a process of professional development [20]. However, according to [38] many teachers will only expend this effort of training when they are convinced of the benefits in terms of learning outcomes.

Several authors highlight the importance of a specific educational environment to take advantage of digital resources, such that facilitates technology usage in an inquiry-based, constructivist manner [38]. Nevertheless, many studies point that digital technologies are "more often used to simply enhance traditional practice" [38]. Other authors [23] claim that teachers may focus on technology and give students little opportunity for mathematical (or science) learning or, on the contrary, focusing mostly on the content and not provide any technology instructions at all.

3 Fundamentals of an Alternative Framework that Permits Facing a Digital Resource as an Epistemic Tool

Everything said next presupposes that the digital resource has the scientific, technical, didactic and usability qualities referred to in [34]. Placing digital resources with interactivity potential at the center of SMT learning (formal and non-formal contexts of learning) may allow for a certain cultural contextualization of learning [4]. In addition, it opens up a field of experimentation in the sense that it allows to verify what is viable, allowing private ideas and perceptions to become public [8] through speech, writing, and productive engagement [6]. Several studies point to the possibility of the use of any digital resource as an "epistemic tool" [7, 9–11]. Even without the concern of using resources as epistemic tools, several studies have been carried out to attribute to the resources a new centrality in SMT teaching and learning [12–17].

3.1 What Is an Artefact, a Tool and an Epistemic Tool?

An artefact is an entity or product of human creation, with embedded knowledge and, in general, with a specific purpose (e.g. sum algorithm, lamp and model) [4, 7–10]. An artefact is, therefore, an entity that is external to the human being and part of the collection of entities created by him/her. A digital resource is an artefact of whatever characteristics and qualities, even if conceived and realized using ICT. A stone or a piece of tree branch are not artefacts: they are objects. However, they can be used as a hammer, that is, as a tool.

As pointed out in [9, 10], our cognition is distributed between individuals and artefacts and largely skill-based and tool-using. When an artefact is used to solve a certain task, that artefact becomes a tool. It is the use for a certain purpose that gives the artefact the status of tool [4, 7]. Therefore, a tool is closely linked to an activity and the use of a tool is directed to the action to obtain a concrete result [7].

In the educational context, transforming the status of a digital resource into a tool can only be done with a task that is authentic and challenging for the students. The algorithm of the sum, instantiated, or not, in an applet, or the model of the photoelectric effect instantiated in a simulation, by themselves, are just artefacts. Both have embedded knowledge. Only when used to solve a task they become tools. The artefacts used as tools to solve a task do not need, a priori, the mobilization of the knowledge embedded in the artefact [9], although it is necessary to mobilize relevant knowledge of the subject [10] for the activity that is being carried out. Therefore, using an artefact in the context of a task with a given purpose, and from which a product (another artefact!) results, confers to it the status of a tool.

If the activity with artefacts, using them as tools, is framed within a "setting of practical action working with representations and a certain materiality to produce knowledge and practices to produce this knowledge", we are within the framework of an epistemic practice [7]. Epistemic practices need a system of knowledge production as practice of solving non-routine problems [7]. The artefacts used in this context and for this purpose acquire the status of epistemic tools [4, 7].

3.2 Conditions to Use a Digital Resource as a Beneficial Tool

Based on [2, 8] we elaborated the concept of "beneficial tool". We defined it, tentatively, as a way of resource use that triggers the students' actions dealing with and solving a problem by allowing them to have cognitive and perceptive experiences that help them externalize, visualize and refine ideas. That is, using a digital resource as a beneficial tool allows to take advantage of its use in terms of interaction, visualization, cognitive and sensory experiences.

Using a digital resource as a beneficial tool is the first level of taking advantage from its educational potential. For this, some conditions are required:

- The digital resource has to have interactivity potentialities and other characteristics identified in [34].
- The task must be designed in order to propose a stimulating challenge and the digital resource is of great help to solve it [22, 33].
- The action taken with the digital resource must mobilize the students' available knowledge [7, 10].
- All action must have a purpose and a clearly identified outcome must result from it [7].
- The use of the digital resource should allow for a field of experimentation of ideas and actions, and should open up the possibility of new cognitive and sensory experiences to emerge [8].

3.3 Instrumental Orchestration

The transformation of an artefact into a tool involves a process of instrumental genesis defined as "the co-emergence of schemes and techniques for using the artefact" [15].

However, studies showed that this process does not occur by itself. The teacher has a relevant role in creating and guiding the learning situations [23], in particular the intentional and systematic organization and use of the digital artefacts in a learning environment [15]. The idea of instrumental orchestration so as "to point out the necessity (for a given institution – a teacher in her/his class, for example) of external steering of students' instrumental genesis" was introduced in 2004 [19].

Trouche [19] considered two elements within an instrumental orchestration: (i) didactical configuration ("a configuration of the teaching setting and the artefacts involved in" the environment) and (ii) exploitation mode ("the way the teacher decides to exploit a didactical configuration for the benefit of his or her didactical intentions"), to which [15] added another: (iii) didactical performance (involves all the teacher performances within the classroom). This last element "constitutes a critical enrichment of the instrumental orchestration model" to enable an orchestration to constitute itself as an artefact for the teacher, and that evolves in different implementations and adaptations in the classroom [4].

Monaghan, Trouche and Borwein [4] stated there are six orchestrations types, most of them established in [15], but not seen as exhaustive: technical-demo, explain-the-screen, link-screen-board, discuss-the-screen, spot-and-show, and sherpa-at-work. The first three are "teacher-centred" and the last three "student-centred", having in mind who dominates the discourse and the action [15, 23].

The instrumental orchestration is a conceptual scheme that embodies the process of becoming a digital resource as a beneficial tool. In the next section, we will extend this conceptual scheme.

3.4 Converting Digital Resources into Tools to Learn

Starting from the idea that a digital resource is an artefact and remembering that an artefact is an entity with knowledge embedded with a specific purpose [4, 7] we have to admit that a digital resource, although with recognized educational potential, does not allow, per se, for educational advantages [15]. Something more is needed. Usually this something else is an exploration guide of a certain digital resource to take educational advantage to learn SMT [31]. An exploratory guide needs to have the artefact status, that is, to embed knowledge of research in science and mathematics education (and others), and not just professional knowledge. This point is fundamental and exploration guides do not always have embedded didactic knowledge.

In other words, the exploration guide must itself result from an epistemic activity combining professional practice and knowledge produced so that it becomes an epistemic artefact [7]. As such, it needs to be flexible and open enough to be used in different cultures [7]. Still, it is well known that another difficulty is for teachers to take ownership of the exploration guide and to acquire the conviction that they can use it [37].

Guiding Principle 1 - A Digital Resource Needs to Have Other Aggregated Epistemic Artefact(s) to be Used for Educational Purposes
From the following, the first idea to be retained is: to take educational advantage of a digital resource, it is necessary to combine another epistemic artefact with embedded knowledge (let us call it exploration guide [31]) with explicit and clear articulations to

the digital resource. In particular, the artefact "exploration guide" should help enrich the potentialities of using artefacts "digital resources".

Corollary 1.1: A digital resource may have various added "exploration guides" artefacts according to learning objectives, educational level, educational context, etc. That is, a digital resource, if combined with different "exploration guides" artefacts, serves different purposes.

In addition, to take educational advantage of a digital resource it is necessary that it be used as a tool. That is, used as an artefact that allows solving problems/tasks. To convert a digital resource into a tool it is necessary to: (a) be used by the students and not by the teacher, and (b) be an activity oriented by a task/problem. This conversion presupposes several changes in the conception and practice of teaching [32]: from passive learning to active learning, from learning concepts to learning in context, from formal abstraction to scaffold abstraction.

Guiding Principle 2 - A Digital Resource Becomes a Tool if Used Effectively to Solve a Task/Problem in a Setting of Learning in Context
From the above, a second idea is to be retained: in order to take educational advantage of a digital resource it is necessary to convert the "digital resource" artefact into a tool. That is, to allow students to use it effectively in an orchestrated activity in a setting of learning in context and oriented towards a task/problem that is authentic and challenging for students [33]. The artefact "exploration guide" should allow the digital resource to be used as a tool in the sense that it allows the execution of actions that trigger answers (e.g. visualizations, calculation of results [13]) that provide digital resource users with an ever closer or more elaborate reply to the task/problem.

Corollary 2.1: A digital resource cannot be used as a tool if there is no authentic and challenging task/problem to solve [33].

Corollary 2.2: A digital resource, when used with an exploration guide, is not a tool if it does not give authority to students when they use it to solve the task/problem [6]. That is, the guidance degree of the exploration guide must allow the use of digital resources by the students with authority.

Corollary 2.3: A digital resource when used with an exploration guide is not a tool if it is not clear what the expected product of the activity is.

Lastly, a student can perform a task without learning anything relevant or new with it. Therefore, it is not enough to use the digital resource as a tool. It is necessary to use the digital resource as a tool to learn, that is, in the context of an epistemic activity. For this to happen, another layer of artefacts is needed: (a) an epistemic artefact that helps to link action and task resolution ("exploration guide" artefact) and (b) an artefact to extend what is learnt to other similar situations or even different situations, since the concepts and procedures learnt can be formulated in a more abstract way to produce conceptual artefacts and, eventually, other.

In other words, an artefact is necessary that, when used, becomes an epistemic tool to shape inquiry action and knowledge production juxtaposing physical and symbolic affordances in order to solve the problem [7]. Therefore, it is necessary that the didactic characteristics of the activity developed in the classroom are consistent with this epistemological approach. In particular, it is necessary to consider the dimensions of production (learning occurs or not by the development of an artefact) and negotiation (learning occurs through discourse with students or negotiated among participants) [35].

We have a longer artefacts chain that must be orchestrated: (a) "digital resource" artefact; (b) "exploration guide" artefact to allow use as (a) a tool; (c) "epistemic tool" artefact to connect (a) with (b) in view of different situations other than those. We extend the concept of instrumental orchestration [4, 15, 19] so that the use of digital resources is: (a) student-centred; (b) inserted in a context of epistemic practices triggered by an authentic task that allows the production of knowledge.

Guiding principle 3 - A Digital Resource Must be Inserted in an Orchestrated Chain of Artefacts, Used in a Setting of Learning in Context of Epistemic Practices, to Allow Connecting the Actionable Knowledge with the Knowledgeable Action

The use of the digital resource needs an artefact orchestration (see Fig. 1):

- "Digital resources" artefacts (type a) with "exploration guides" artefacts (type b) that focus students on action based on previous knowledge (actionable knowledge – knowing what to do, how to do, why to do [7]); and,
- Artefacts type (b) with epistemic artefacts (type c) that focus students on what can be learned from the action (knowledgeable action – using artefacts to describe, explain, and make explicit underlying principles or models, using symbolic representations [7]).

The artefacts orchestration of different artefacts should be centred on epistemic practices and procedures that allow the students to move beyond what is known. Among epistemic practices are awareness activities such as describing a phenomenon or event, or performing operations with representations that create conditions for interpreting, arguing, modelling, or even communicating a result.

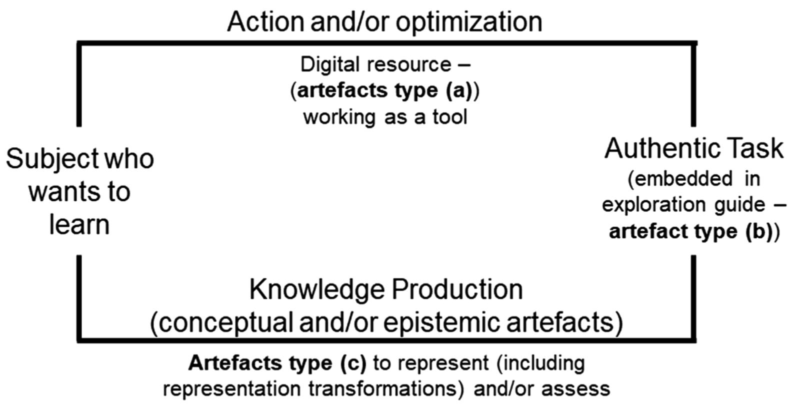

Fig. 1. Artefacts orchestration to connect actionable knowledge with the action knowledgeable in the learning context of epistemic practices.

Corollary 3.1: A digital resource is not a tool to learn if it does not allow action with meaning and relevance to solve a problem that results in an outcome (conceptual or epistemic artefacts).

Corollary 3.2: A digital resource is not a tool to learn if there are no epistemic practices from which a theoretical approach becomes relevant and necessary.

Corollary 3.3: A digital resource is not a tool to learn if there is no orchestration of the different types of artefacts (orchestration of artefacts type (a) with type (b) and type (c)) that can lead to a virtuous cycle of acting-assess-represent-optimize [7, 36], where learning occurs by the development of an artefact [35] and/or by the representation of different levels of conceptualization (description, explanation, principles and theories) [7].

4 Key Points to a Change in Teaching Practices and Research

In this section, we present three examples of how the ideas presented in Sect. 3 can be instantiated. It is also discussed what aspects need to be considered in a research program that seeks answers in order to take advantage of the many available digital resources. Some of them, even without being designed for educational purposes, can be used for educational purposes.

4.1 Examples of Some Practice Change Projects

The examples reported in this subsection are the result of research with the general goal of taking advantage of available resources, first turning them into tools and then into epistemic tools.

Example 1 - The Use of Visual Representations: From an Artefact to an Epistemic Tool. Visual representations are not the most common representations used in mathematics teaching and learning. However, visual representations are artefacts (entities that result from human creation, with embedded knowledge), and therefore, with an appropriate exploitation mode and didactical performance, could become a tool, a beneficial or an epistemic tool. That is what Montenegro, Costa and Lopes did in [39]. The authors were interested in investigating the impact of the use of visual representations in teaching and learning early algebra (with 18 students aged between 10 and 13). To do so, an instrumental orchestration was designed, with characteristics (a), (b) and (c), and resulted in the artefacts orchestration presented in (d):

(a) Didactical configuration: use of a visual representation of a pattern in a task taken from the students' textbook in a 40-min session, with the didactic aim of consolidating and reviewing the learning achieved in the topic of Sequences and Regularities;
(b) Exploitation mode: explore in two previous lessons some visual and numerical growth patterns, focusing on the analysis of regularities, in different systems of representations, and on the relationship between this and other pre-achieved knowledge. In the third lesson, the students solved the task involving the visual

pattern, in groups of four. As usual, the teacher circulated among the groups to ensure that productive work was being done but having in mind students should conclude the task with the maximum autonomy in the time available.

(c) Didactical performance: the teacher intervened in both groups when she noticed discontinuities in the groups' activity. Only one group explicitly requested the teacher's help. The teacher intervention was in the sense of showing the potential value in exploring the visual representation. As her suggestion of taking a closer look to the drawings to find similarities and differences did not work, she highlighted what was constant from one figure to the next, drawing and talking to the students. After some interaction, "the students exclaimed 'Ahhhhh!'", [39] and quickly solved the problem.

(d) Artefacts orchestration: artefact type (a) is the visual representation; artefact type (b) is the task and the teacher exploitation mode and didactical performance; together they promote the actionable knowledge, and visual representations appropriated by students become epistemic tools, since they started to use them on their own initiative in other situations. The paper [39] in which the study research is presented constitutes a new artefact that can be used as a tool by those who read and use it in their professional or research practices. Moreover, the virtuous cycle goes on.

Example 2 - Culture as Didactical Resource: An Example of a Complete Virtuous Cycle of Artefacts. Claiming that the ancestral culture of the students can be an engaging element for the learning of mathematics, a research study [40] was implemented with the objective of understanding how teachers from the north of Portugal appropriated intentionally created resources (artefacts), giving prominence to the cultural context. The researchers created artefacts, which they called transverse resources, taking account of the cultural context and in order to allow the mathematical content to be adapted to different levels of schooling. These transversal resources were presented and explained to several teachers and were worked by them in a continuous training course, giving rise to new resources (artefacts) that they applied to their students. Thus, an instrumental orchestration was designed composed by: (a) the transverse resources and the new resources (didactical configuration); (b) the continuous training course and the teaching mode that each teacher chose to apply the new resource, mainly solving tasks in groups (exploitation mode); (c) the interactions done by a researcher in the continuous training course and the ones done by each teacher, participant in the study. In fact, there were many instrumental orchestrations, a first one designed by researchers that transformed the artefacts – transversal resources – into tools, beneficial tools and epistemic tools; and the ones originated by this and designed by each teacher to implement "his/her" artefact – the new resource. Results showed that some of the teachers appropriated the transversal artefacts as beneficial tools and went further creating new artefacts with the same objective but clearly different from the transversal resources, closing the artefacts orchestration cycle (see Fig. 1) presented in Sect. 3.4. Other teachers, although not creating a completely new resource, did several modifications having into account his/her students, and others just made minimum adaptations to the transversal resources.

Example 3 - Influence of the Guidance Degree of Exploration Guide to Use a Computational Simulation on Learning Outcomes. The work of [26] consisted in studying the influence of the guidance degree of exploration guide to use a computational simulation on learning outcomes concerning the physical state of matter at microscope level with students aged 9–11. The study was of a quasi-experimental type, with pre- and post-test, in four groups of students: one with minimal guidance degree of exploration guide, one with high guidance degree and two with the same moderate guidance degree.

Artefacts Orchestration to Mobilize Actionable Knowledge

(a) Didactical configuration: Once the digital resource to be used was chosen ("states-of-matter-basic" simulation of PhET project), the researchers studied the characteristics of the simulation: usability, scientific aspects, possible simulation circumstances that can induce alternative conceptions, interactivity possibilities, variables that could be studied, and constraints inherent in the simulation itself. It was only with this study that it was possible to design exploration guides with different guidance degrees. First of all, it was necessary to concentrate efforts to conceive an authentic task from the perspective of the students. At this point the teacher's experience was decisive. The established task was the same for all exploration guides.

(b) Exploitation mode: The next step was to determine the guidance degree for each type of exploration guide. As it is well known, this is a matter of debate because of the complexity of the subject and the reliance on not easily controllable circumstances. The research effort of [26] focused precisely on studying the influence of the guidance degree of exploration guide to use the computational simulation on learning outcomes, in particular as regards conceptual recognition or elaboration. The results indicate higher gains in the groups that used an exploration guide with a moderate guidance degree, as compared to the remaining two groups.

(c) Didactical performance: Precisely because the researchers are aware of the fact that an exploration guide with moderate guidance degree has a greater possibility to develop higher quality learning but is more dependent on the didactical performance of the teacher, is that the didactical performance of a same teacher was studied in groups of distinct students, using a same exploration guide with moderate guidance degree. The results obtained show fluctuations in student performance that need to be studied in more detail.

Artefacts Orchestration to Produce Knowledge. The research of [26] is ongoing. The next phase is to study how different groups of students can use simulations with exploration guides with a moderate guidance degree. The teaching didactical performance will be first decisive for creating a learning context of epistemic practices. Another decisive aspect is that the learning context is marked by the need to obtain products (conceptual or epistemic artefact or new practices). Finally, it is necessary that epistemic artefacts be used to represent operations with simulations, their results and how to transform representations or to make practices explicit and aware that lead to the construction of practical and theoretical knowledge (see Example 1).

4.2 Key Points for a Research Program to Convert Digital Resources in SMT Teaching into Tools to Learn

As we said earlier, a digital resource, per se, does not guarantee that we will take educational advantage of it. The first difficulty is the intrinsic quality of the digital resource. The second difficulty is how to convert a digital artefact resource into a tool for educational benefit. The theorization proposed by [4, 15, 19] on instrumental orchestration lacks several theoretical and practical insights. And, finally, connecting actionable knowledge with knowledgeable action in the learning context of epistemic practices is something that is glimpsed from the theoretical point of view, but still lacks more theoretical and practical deepening.

Although we know the aspects mentioned in the three examples above, the "artefact orchestration" to produce knowledge remains a challenge because it imposes changes in the teacher's teaching practices and in his/her performance and can also lead to the reformulation of the exploration guide. Many aspects of this "artefact orchestration" are unclear when a digital resource is regarded as an epistemic tool. We are convinced that this line of work is, however, very promising, for its openness to designing and establishing effective principles of effective learning settings that are focused on epistemic practices and use digital resources. These learning settings allow developing a new range of competencies demanded in various sectors, such as critical and creative thinking.

The research program we propose has three axes and presents four outcomes, and is strongly based on the scheme in Fig. 1.

Axe 1 – Identify the educational potentialities of any digital resources, including those that were not designed for formal educational purposes, and those that were designed for non-formal educational purposes (e.g. serious games).

Axe 2 – Study how an artefact, a digital resource, can be converted into a tool, taking into account the concepts of authentic task, guidance degree of the exploration guide, and how these can be articulated in an adequate didactical configuration, exploitation mode, and didactical performance.

Axe 3 – Study how to convert the conventional learning settings into learning contexts of epistemic practices to produce knowledge (conceptual artefacts), practices, and outcomes (epistemic artefacts), in which digital resources play a central role because they allow for distributed cognition [7–10].

Outcomes 1 to 3: An epistemic artefact per axis which allows any teacher to: (a) choose a digital resource (b) design an adequate didactical configuration, exploitation mode, and didactical performance, (c) design a learning context of epistemic practices to produce knowledge (conceptual artefacts), practices, and outcomes (epistemic artefacts), in which digital resources play a central role.

Outcome 4: An epistemic artefact, which allows any teacher to link the three epistemic artefacts referred above.

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Digital Learning Objects for Teaching Computer Programming in Primary Students

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Abstract. The current learning environments focus on the development of skills which are related to problem solving, creativity and critical thinking addressing the needs of learners in today's society. Computer programming includes this kind of skills and it is placed at the center of attention of the educational policy. Approaching programming is a difficult task because of its complex concepts, thus educators are seeking effective methods for teaching it. This paper presents the design of digital learning objects for teaching programming concepts and the results of a pilot empirical study with special users. The results reveal that the proposed learning objects seem to be a useful tool for teachers, aligned with the learning goals and can be employed in authentic scenarios.

Keywords: Computer science education · Computer programming · Scratch · Learning objects · Primary students

1 Introduction

Today's learning environments focus on developing problem solving skills, critical thinking and creativity [1, 2]. Learning computer programming cultivates design skills and allows students to experience solving to solving problems and making connections online [3–6]. Computer programming is directly associated with the development of computational and algorithmic thinking as it allows the students to engage in knowledge-building procedures through meaningful activities [3].

The introduction of computer programming in educational settings occurs at a global level. In primary education, computer programming courses teach computational concepts that are common in many programming languages and can be transferred to other contexts (programming and non-programming ones). These concepts are:

- sequence: identifying a series of steps for a task
- loops: running the same sequence multiple times
- conditionals: making decisions based on conditions
- events: one thing causing another thing to happen

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- message transmission: triggering sections/commands of a code across different sprites

The literature suggests that computer programming is a difficult task for students because it comes along with complex and abstract concepts that discourage the students [7–12], which makes it also more difficult for teachers to explain the syntax and the logic behind the codes [13, 14]. Thus, educators are looking for efficient and motivate ways to teach them [15]. Unplugged activities, game based learning, educational robotics and pleasant programming environments have been found to be effective means for helping learners to construct knowledge.

Reusable digital educational resources have been developed and applied in many disciplines and have yielded significant contributions to the effective teaching of programming. These resources range from micro-activities or micro-lessons to open-ended applications. Among them, the learning objects (LOs) have been proven to be quite effective [16–18]. The aim of the present paper was the design of LOs to teach the five basic computer programming structures, namely sequence, loops, conditionals, events, and message transmission among sprites. A pilot study with special users, Computer Science teachers, followed.

1.1 Learning Objects for Teaching Programming

We define a Learning Object as a small, self-contained, reusable and pedagogical complete structure of learning content called as a knowledge "package" [19] attempting to deliver learning experiences [20, 21]. In brief, the LOs should come along with high levels of reusability, granularity, discoverability, accessibility, interoperability, adaptability, durability, generativity and manageability [22].

Based on our literature review regarding the creation of learning objects for teaching Computer Science and especially for programming, we have identified 12 relevant studies. Most of these studies targeted secondary and higher education students [8–10, 12, 23–30]. All the authors underline the great impact that LOs have had on learners (cultivation of algorithmic and problem-solving thinking, understanding of incomprehensive programming concepts, promoting enthusiasm and positive attitude toward programming as a subject). Out of the 12 studies reviewed, 9 have targeted university students and 3 have targeted secondary students. There were no studies focusing on LOs in primary education. This literature gap has led to the design of the LOs presented in this work.

2 Methodology

2.1 Sample and Data Collection Process

To satisfy the current research interest, the authors conducted a pilot empirical study with a sample of four Computer Science teachers with experience in teaching computer programing. Before the pilot study, an expert user checked the LOs regarding the user interface and layout, the codes of the LOs and the assessment tool to ensure its alignment with the learning goals we have put in each one of the LOs.

The pilot study's sample is from primary and secondary education with more than ten years of experience. Since the programming principles in the Greek educational system are taught starting from the last two years of primary school until the end of the secondary school, the sample was selected to ensure representation of the different educational levels.

The participants received the developed LOs by e-mail together with brief instructions explaining how they work. Data was collected online over a one-week period. The Learning Object Review Instrument-LORI [31] was used as the assessment tool including Likert scale items and one open-ended question asking for the participants' feedback on the LOs. LORI is a tool which evaluates the quality of the LOs taking into account the aspects of reusability, granularity, discoverability, accessibility, interoperability, adaptability, durability, generativity and manageability. LORI was distributed using Google Forms. The link to the questionnaire was in the e-mail sent to the subjects. The data coming from the evaluations were analyzed with SPSS for descriptive statistical analysis in the cases of the Likert scale questions and by content analysis in the case of the open-ended question. Each of the four participants assessed the LOs evaluating the aspects of context quality of the LOs, the alignment with the learning goal, the feedback provided to the users, the presentation design and the motivation, the interaction usability, the reusability and the accessibility of the LOs.

2.2 Design and Development of the Learning Objects

Seven LOs were developed in the Scratch programming environment. Scratch was selected because it is intuitive and easy to learn by students and it supports constructive learning [32]. Additionally, Scratch is used in schools around the world as a means to introduce basic computer programming to students, especially to younger ones without prior experience. Most importantly, Computer Science teachers can freely use the codes of the LOs to modify them according to their specific context and needs so it is more affordable for them since they don't have to develop new material from zero.

In four months, we designed and developed seven LOs focusing on the structures of sequence, repetition (loops), selection (if & if/else) and transmission (broadcast/ when I receive). Each LO has as main "actor" an elf, which the users (i.e., students) have to program it correctly in order to perform a particular action of repetition, selection and/or message transmission and communication between other sprites.

The developed LOs are reusable and adaptable; they can be shared easily among users and edited according to different needs. They are characterized by granularity; they are small enough to be used easily in different contexts, yet large enough to be meaningful for the students. They are manageable, and they can be updated, revised and combined with other LOs since they are open code. They can be understood easily by others because they come with metadata which include a detailed description of each object. Finally, they work in different operating systems and browsers since they can run in Scratch 2.0.

The user interface of the LOs was intended to resemble the user interface of Scratch (Fig. 1). The researcher programmed a Scratch environment inside Scratch, with the figures, the blocks and the main buttons designed to function in the same way as in the "real" Scratch.

Fig. 1. Snapshot of the main programming interface of the users.

– Sequence LO: The aim of this LO was to introduce the concept of the sequence of steps that are needed to complete a code. The student's goal is to program correctly the elf to reach the piece of wood in front of him, by jumping on the bushes (Fig. 2).
– Loop LOs: We have created four LOs regarding the loop concept. Their aim was to underline the importance of the repetition command and to give the students the opportunity to practice with the execution of codes starting from easy ones and ending with more complex ones. Students have to use fruitfully the repeat block leading the elf to the tree (Fig. 3).
– Conditional LO: The aim of this LO was to help the students understand that every decision is based on conditions. The goal of the activity is to program the elf to wait while the spider is appearing in the scene (Fig. 4).
– Conditional and Event LO: These LOs aimed to teach that different events are executed in a different way based on the condition of a problem situation. The goal is to program the elf to wait if the spider is present in the scene, and otherwise jump into the bushes (Fig. 5).
– Message Transmission-among-sprites LO: The aim of this LO was to make the students feel comfortable with the abstract idea of message transmission. The users have to program correctly two scenarios, one for each sprite using the blocks which accompany each one, resulting in the elf transmitting a message to the spider, which executes its code upon receiving the message (Fig. 6).

The above LOs are designed to be simple enough and intuitive, to be used by teachers without any specific experience in programming, to be reusable and to be easily shared among other educators. They are open so that others can easily modified them. Additionally, they provide direct feedback and proper scaffolding to the users.

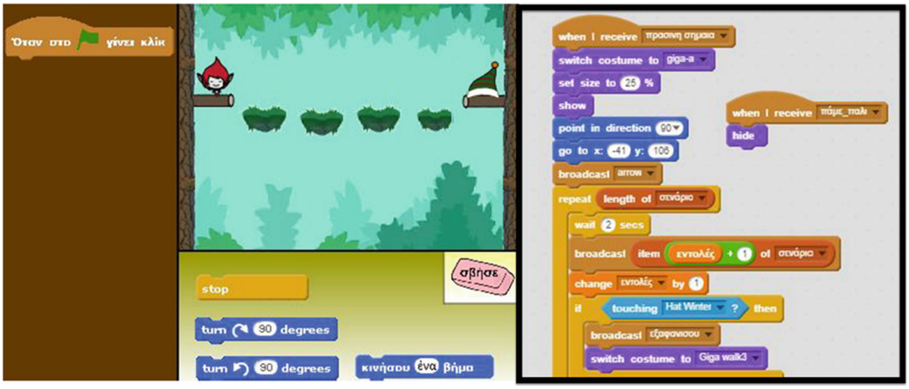

Fig. 2. Left: The interface of the Sequence LO which the students can see and interact with. Right: a code example of the LO made by the instructor which the students cannot see

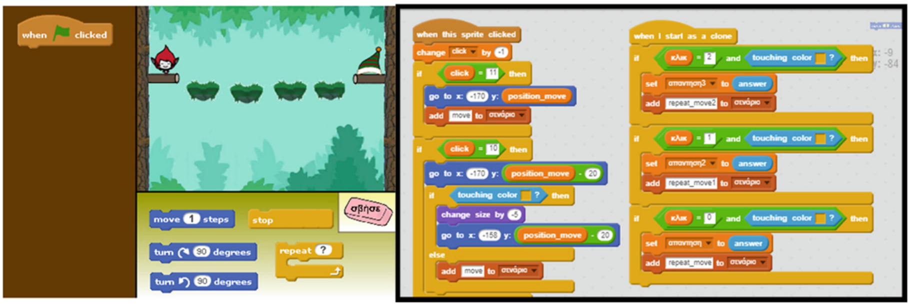

Fig. 3. Left: The interface of the Loop1 LO which the students can see and interact with. Right: a code example of the LO made by the instructor which the students cannot see

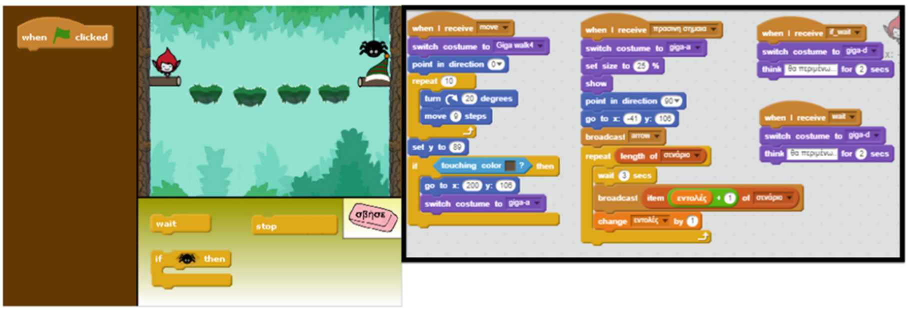

Fig. 4. Left: The interface of the Conditional LO which the students can see and interact with. Right: a code example of the LO made by the instructor which the students cannot see

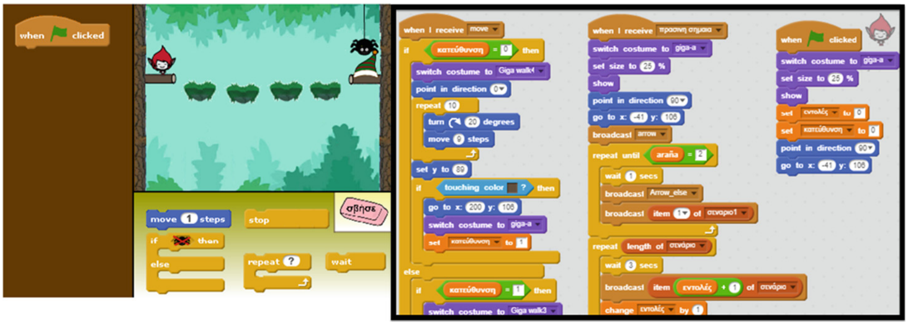

Fig. 5. Left: The interface of the Conditional-Event LO which the students can see and interact with. Right: a code example of the LO made by the instructor which the students cannot see

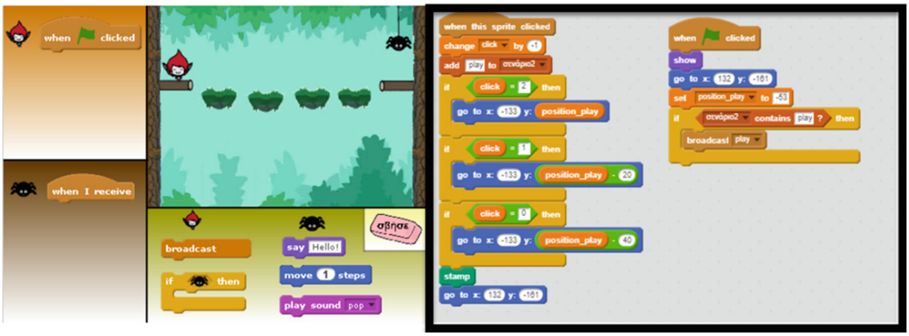

Fig. 6. Left: The interface of this LO which the students can see and interact with. Right: a code example of the LO made by the instructor which the students cannot see

3 Results of the Pilot Study

The evaluation of the LOs was based on the questions regarding the instructional design of the LOs (quantitative data) and the comments made by the educators as feedback (qualitative data).

The analysis of the questions regarding the instructional design of LOs (see Appendix, Table 1) indicated that the participants were in general satisfied by the LOs. The parameters of content quality (total M = 3,83), learning goal alignment (total M = 4,17) and presentation design (total M = 4) have been rated higher than the others and the ones of adaptation total (M = 3,42) and accessibility (total M = 2,67) a bit lower. In short, the content seemed to be free of errors without bias or omissions that could mislead the students, the learning activities were well-aligned with the declared goals, and the various graphics to highlight the key points and the important ideas were presented with appropriate level of details.

The analysis of the feedback provided by the teachers in open-ended questions has led to two categories: positive comments and future improvements (see Appendix,

Table 2). Some examples are: “nice original work”, “fruitful messages when the user makes errors in the code”, “some parts of the instructions need more details”.

4 Discussion and Conclusions

The current paper presents the design and development of seven LOs for teaching the basic computer programming structures to primary students without prior experience in programming using Scratch environment. The significance of this work lays on the lack of literature on this topic.

The findings have shown good evidence indicating the potentials of LOs as tools for teaching Computer Science to primary school students; they were aligned with the learning goals and they explained abstract concepts in a clearer and more enjoying way. Our results are in accordance with other similar studies like the ones of [24], who highlighted the importance of LOs because they help students to understand abstract concepts through visualization and the ones of [9] and [23], according to whom, the use of LOs led to the stimulation of the interest of the students.

After the pilot study, we made the following adjustments:

- The interface design of the LOs was refined. The central elf figure has been replaced by a frog one (Fig. 7) because, according to the teachers’ feedback, the LOs should represent real examples and everyday situations with which the students are familiar. Additionally, some elements of the layout-like some key buttons- have been changed in color and size to avoid the students’ confusion.
- Some parts of the code were optimized by the expert user during the alpha and beta tests.
- Five out of seven LOs were finally chosen. We have kept three out of the four Loop LOs and we have excluded the conditional LO. These changes were made based on the comments of the participants of the pilot study and the expert user, those two rejected LOs were overlapping with the rest ones.

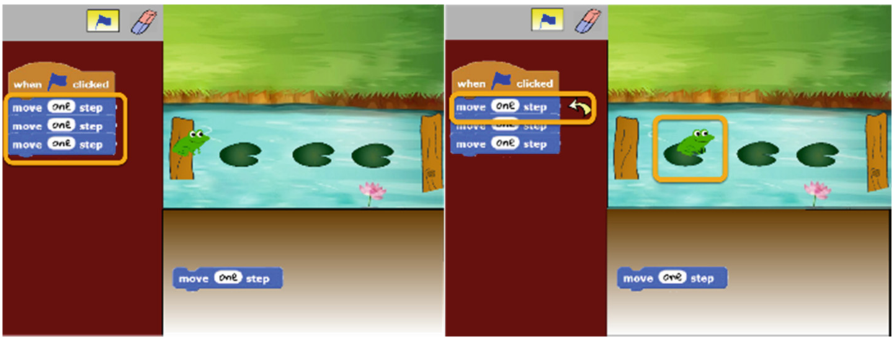

Fig. 7. Snapshot of the users’ interface of the Sequence LO while executing their code

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Appendix

(See Tables 1 and 2).

Table 1. Learning objects assessment -Likert items.

Questions	Mean	St. deviation
I. Context quality	***3,83***	
The content is free of errors and is presented without bias or omissions that could mislead the students	3,75	,50
The content is scientifically correct	4,00	,82
Graphics highlight the key points and the important ideas with the appropriate level of detail	3,75	,50
II. Learning goal alignment	***4,17***	
The learning goals are appropriate for the intended students. The learning objects work autonomously and contribute to the achievement of learning goals	4,50	,58
The learning activities, content and the possible assessments provided by the object align with the declared goals	4,00	,82
The learning objects work autonomously and contribute to the achievement of the desired learning goals	4,00	,82
III. Feedback & adaptation	***3,42***	
The learning objects have the ability to tailor instructional messages or activities according to the specific needs or characteristics of each learner	3,50	1,00
The learning objects have the ability to simulate or construct phenomena under study in response to differential input from the learner	3,50	1,29
IV. Motivation	***3,83***	
The learning objects are highly motivating. Their content is relevant to the personal goals and interests of the intended learners	4,25	,58
The object offers choice, true-to-life learning activities, multimedia, interactivity, humor, drama, or game-like challenges. It provides realistic expectations and criteria for success	3,75	,82
Learners are likely to report an increased interest in the topic after working with the learning objects	3,50	,58
V. Presentation design	4,00	
Content contributes to positive learning outcomes. The language is clear, comprehensive and error free	4,00	,82

(*continued*)

Table 1. (*continued*)

Questions	Mean	St. deviation
Graphics minimize the visual search	3,50	,58
The text is legible	4,50	,58
VI. Interaction usability	***3,62***	
The user interface design implicitly informs learners how to interact with the object, or there are clear instructions guiding use. Navigation through the object is easy, intuitive and free from excessive delay	3,50	1,00
The behavior of the user interface is consistent and predictable	3,75	1,26
VII. Reusability	***3,50***	
The learning object is a standalone resource that can be readily transferred to different courses, learning designs and contexts without modification	3,50	1,00
It operates effectively with a broad range of learners by adapting content or providing adjunctive content such as glossaries and summaries of prerequisite concepts	3,50	1,29
VIII. Accessibility	2,67	
The learning object is accessible using assistive devices for users with sensory and physical disabilities. It is also accessible via portable devices	2,67	,58

Table 2. Learning objects assessment-sample's feedback

Positive comments	Possible improvements
Factors	Factors
Feedback	Slow pace
Entertainment	Personalized feedback
Originality of the idea	Additional guidelines per LO
Alignment with the learning objectives	Improvement of the code behind the LOs

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Learning Effects of Different Digital-Based Approaches in Chemistry: A Quasi-experimental Assessment

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Abstract. This study aimed at assessing the learning effects of different ways of integrating digital educational resources in chemistry education. The alternative hypothesis is that digital educational resources contribute more effectively for students' learning than pen-and-paper consolidation worksheets. A sample of 61 students participated in a pretest-posttest quasi-experimental design with four conditions (control, and three digital-based approaches: outside the classroom individual approach, inside the classroom individual approach, inside the classroom group approach). Three digital educational resources were developed to address three chemistry themes (particle motion, gas pressure, and electric current through a solution). Results revealed that the inside the classroom individual digital-based approach and the outside the classroom individual digital-based approach were more effective in helping students to perform better, thus partially supporting the alternative hypothesis. The study contributed for the progress of the state of the art by drawing our attention to the plethora of phenomena around the use of computer-based technologies in education, in particular, highlighting the need to consider carefully the resources and pedagogical strategies underpinning one-to-one computing.

Keywords: Digital educational resources · Chemistry education · Quasi-experimental design · Cognitive tools

1 Introduction

Modern computer-based technologies opened new avenues in science teaching and learning. Technology can fulfil multiple tasks in the educational context (e.g. productivity tool, creativity tool, communication channel, source of information and of resources). However, one of our greatest challenges lies in being able to ensure that technology is used to improve meaningful learning [1–5].

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2 Digital Educational Resources (DER)

2.1 Cognitive Tools

According to [6], we should consider technology as a cognitive tool, that promotes meaningful learning whenever students: (i) interact with objects, observe the effects of their interventions and construct their own interpretations; (ii) integrate new experiences and new interpretations with their previous knowledge about reality; (iii) articulate their learning goals with what they do, the decisions they make, the strategies they use and the answers they reach; (iv) perform learning tasks based on real life situations; and (v) work in groups, negotiating their social expectations and the choice of tasks and methods to achieve their goals.

Computer simulations, in particular, have been perceived as prosperous technological tools for science teaching and learning [7]. Simulations allow to directly manipulate initial conditions and straightforwardly see the results [8]. Furthermore, through the use of computer simulations and animations, also, it is possible to observe events which cannot be directly seen because they may be very large or very small, very slow or very fast and too complex [9, 10].

In chemistry, through the exploration of simulations, learners are able to test assumptions, dynamically view illustrations at the molecular level, that draw their attention to patterns and contrasts using graphs and rich animations, making, thus, unobservable processes more explicit [11, 12].

Computer simulations and animations give an enormous variety of possibilities of modelling concepts and processes. Because chemistry involves many abstract and complex concepts [13], models are very important. Through them, observed phenomena are reconceptualised not only at the macroscopic level, but also in terms of the theoretical models of the structure of matter at the submicroscopic level [14, 15]. According to [15]: "for the chemist, models of the world at the submicroscopic scale of molecules, ions, and electrons do useful explanatory work, because the properties of those "particles" (i.e., the molecules, ions, electrons, etc.) are understood to interact to give rise to structures at the phenomenological macroscopic level, so they lead to the emergent properties that can be observed. This has long been a metaphysical premise of chemistry".

2.2 Pedagogical Integration

For more than three decades several studies have pointed out the potentially positive impact of the use of computer simulations and animations on instructional approaches, boosting the development of skills, attitudes, and conceptual understanding [7, 8, 16–18]. However, as [7] emphasize in most of this research the use of these computer-based technologies has been approached without consideration of the possible impact of teacher or the support material that can be developed by teacher, the lesson scenario, and the computer-based technologies place within the curriculum. Moreover, as [19] stress, we should not overlook the effects of the way technology is used. Regarding materials for supporting learners during their interaction with computer simulations, in particular, [20] present the "exploration guides". "The exploration guides can serve to adjust the same software program to several learning levels […] an exploration guide can be created for lesson purposes, but it can also raise questions and challenges intended to be explored later. This useful extension outside of school is possible […]" [20].

According to [21], "while Vygotsky's role of the more knowledgeable other [MKO] is traditionally portrayed as a teacher, paraprofessional, sibling, or advanced classmate, technology allows for a new definition to be written, one that celebrates students driving their own instruction with masterful guidance from teachers." In some situations, MKO might be a computer simulation or animation and an exploration guide that, at least, creates: (a) a peer collaboration experience inside the classroom; (b) an individualized tutoring series for students, who are inside the classroom or outside the school.

As [20] point out, when students interact with computer simulations and animations, alone or in a group without an exploration guide, they may click through these resources, most of the time without an appropriate reflection that would allow them to build and strengthen their learning; losing opportunities for metacognition and awareness of their previous difficulties.

The interaction among students generates extra activities, such as: explanation, disagreement and mutual regulation, which trigger extra cognitive mechanisms, e.g. knowledge elicitation, internalisation, reduced cognitive load. These may occur more frequently in collaborative learning than in individual condition [22]. More than individual and group condition within classroom, our option for extend classroom boundaries through the homework is based on the idea that the relationship between the amount of homework students do and their achievement results is positive and statistically significant [23]. The homework completion may have one word to say about the improvement of self-regulation, managing distractions, self-efficacy, perceived responsibility for learning, self-reflection and managing time [24]. Moreover, it includes elaborating on information addressed in the class or opportunities for students to explore the key concept in areas of their own interest. The chances for using the classroom time for the application and deeper exploration of information addressed in the homework should not be forgotten.

Regarding the one-to-one computing place within the curriculum, more than curricular guidelines that incentive the use of computer simulations and animations in chemistry teaching, it is crucial to selected and sometimes to produce digital resources that fit the curriculum learning outcomes, are suitable for students of a certain age and present the contents in Portuguese language (students' mother tongue). In the case of the present research we designed two computer simulations and one computer animation, taking into account specific characteristics of the target audience of students that would interact with them, and all the particularities associated with the study of chemistry, that were addressed before.

One word must be said in order to distinguish computer simulations and computer animation in our research. In computer animation, the information is presented using different media - a structured auditory narrative, complemented with important animated illustrations and some notes in text format. The audio and the animated illustrations are strong elements of the multimedia matrix in computer animation. It should also be noted that, contrary to computer simulations, the animation does not lend itself to a high level of interaction in terms of manipulation of variables. However, it allows access control commands of the auditory narrative. Thus, the user (student) can manage the pace at which the information appears but cannot interact with the environment that is being shown or manipulate variables such as in computer simulations.

Each DER was supported by an exploration guide and addressed a specific chemistry content (i.e., particle motion, gas pressure, and electric current through a solution). One of the key features that we tried to include in the design of the computer simulations was the representation of processes at the microscopic level facilitating the understanding of the essence of most macroscopic chemical phenomena.

Our alternative hypothesis is that the integration of DER supported by exploration guides will contribute more effectively than pen-and-paper consolidation worksheets, for students learning. We are further interested in finding out the simple effects of each integration approach of DER in helping students presenting better learning results.

3 Methods

3.1 Participants and Design

The field work for this research involved a sample of 61 eighth grade students (average 13 years old) and their own teacher, and took place during the second and third terms of the school year 2009/2010 [25].

The quasi-experimental design consisted of four conditions with pre- and posttest. In the control group (CG), students (n = 19) did not interact with the DER. As homework, CG group was engaged in pen-and-paper consolidation activities about the lectured contents, in particular, solving exercises and problems from their text books. In the other three conditions, students interacted with the DER and was accompanied by exploration guides, in which students could find information about the ways that they should interact with the DER (sequence of options, variables selected, etc.) and intercalary interpretative questions about the different phenomenon that were being shown in DER. The students had to find the correct answers for the questions, taking advantage to the interaction with DER and thinking scientifically about the meaning of macroscopy and microscopy things and their relations.

There were differences, however, in the way students interacted with the DER. In the inside the classroom individual digital-based approach (ICIA), students (n = 11) interacted with the software individually inside the classroom. In the inside the classroom group digital-based approach (ICGA), students (n = 11) interacted with the DER in small groups inside the classroom. In the outside the classroom individual digital-based approach (OCIA), students (n = 20) interacted with the DER outside the classroom. Inside the classroom the interaction took place during three classes of 90 min each in three different weeks. Teacher's support was reduced to logistical issues, such as internet or computers support or class organization. For students, who interacted with the DER outside the classroom, the teacher also recommend that they spend the maximum of 90 min in each DER.

3.2 Materials

Two computer simulations and one computer animation were developed (which were later made available for the community by a national publisher). These DER are available online (http://www.emultimedia.com.pt/alunos/?cat=6) and are presented below:

DER 1: Particle motion. This computer simulation aimed to help students understand that matter is made up of particles in continuous motion, and that these particles move incessantly, whether it is a solid material, a liquid or a gas, although the particle motion might be more limited when we deal with a solid or a liquid than with a gas. Moreover, this simulation may also be helpful in establishing associations between temperature change and increase or decrease in particle motion. An understanding of the relationship between the states of matter, the particle structure of matter, and the properties of materials might also be enhanced by the computer simulation (Fig. 1).

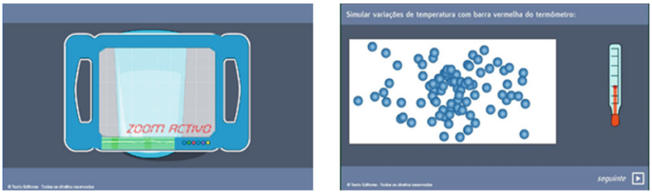

Fig. 1. Screen of the simulation showing the microscopic level representation of liquid water particles, using a zoom in tool.

DER 2: Gas pressure. The purpose of this computer simulation was to show the relationship between gas pressure changes and volume and temperature changes. Showing the dynamic relation among these variables, and allowing the interaction with volume and temperature, observing the changes in the pressure, might help students to significantly understand the interdependence among volume, temperature and pressure (Fig. 2).

Fig. 2. Screen of the simulation allowing the interaction with volume and temperature and showing the pressure's changes.

DER 3: *Electric current through a solution*. Based on the understanding that matter consists of atoms, molecules, and ions (positive and negative), this DER had the main purpose of assisting students to understand that ionic compounds (made up of ions), when dissolved, are able to conduct electricity. This DER aimed to highlight the strong relation between the representation of processes at the microscopic level facilitating the understanding of the essence of macroscopic phenomena; in this case a bulb that lights up, when introduced inside an electric circuit (Fig. 3).

Fig. 3. Screen showing the microscopic level representation and ion motion within a solution and its relation with lighting up a bulb, at a macroscopic level.

Each digital resource was expected to enhance specific learning outcomes as listed in Table 1.

Table 1. Learning outcomes enhanced by each digital resource developed.

Digital resources	Specific learning outcomes
Particle motion	- To understand that matter is made up of particles - atoms, molecules and ions - in continuous motion - To recognize that the size of the particles that constitute matter is extremely small and that they are invisible to the naked eye - To describe the states of matter in terms of the particle structure of matter and to understand that proximity and bonds between the particles influence the properties of materials - To recognize that particles in gases move more freely than in liquids and solids - To relate changes in temperature with the particle structure of matter and particle motion
Gas pressure	- To relate gas pressure with the collisions of particles against surfaces - To interpret how changes in gas pressure influence changes in volume - To interpret how changes in gas pressure influence changes in temperature
Electric current through a solution	- To understand the meaning of "ionic compound" and to recognize the existence of positive and negative ions, identifying them and representing them accordingly - To identify positive ions as cations and negative ions as anions - To understand that ionic substances conduct electricity when they are molten or in solution, and to recognize the macroscopic evidences of this phenomenon - To understand the role of the electrodes and the movement of the ions in solution

The pen-and-paper pre and posttest questionnaire was designed in accordance with learning outcomes determined by the curricula, associated with the school level (eighth grade), and bearing in mind the computer simulations developed in order to address them (see Table 1).

The questionnaire had a total of ten questions, four of them regarding particle motion, other three questions regarding gas pressure and three about electric current through a solution.

Reliability based on standardized items about the learning outcomes associated with DER 1 (four items) was questionable in the pretest and acceptable in the post-test (pre-test: $\alpha = .68$; posttest: $\alpha = .78$). Reliability based on standardized items about the learning outcomes associated with DER 2 (three items) was excellent both in the pre- and post-test (pre-test: $\alpha = .93$; post-test: $\alpha = .97$). The reliability based on standardized items about the learning outcomes associated with DER 3 (three items) was unacceptable both in the pre- and post-test (pre-test: $\alpha = .41$; post-test: $\alpha = .42$). Thus, we deleted the last item and obtained a correlation between the two remaining items (pre-test: $r = .38$, $p < .001$; post-test: $r = .48$; $p < .001$). Thus, we created composite measure for each group of learning outcomes.

Accordingly, we deleted the said item when computing the global reliability based on standardized items of the pre-test and post-test. was questionable (pre-test: $\alpha = .68$). However, as the reliability based on standardized items of the post-test was good ($\alpha = .88$), we decided to create composite measures of the pre- and post-test.

3.3 Procedures

Before starting the action with students that integrated our sample, there was a "personalized" teacher training meetings. The intervention program was fully explained and the various DER were explored together with the teacher. Throughout the fieldwork, we tried to follow closely the teacher, supporting and guiding the integration of DER with her students.

Previous to the students' interaction with the DER, a questionnaire was applied, as a pre-test, to the four research conditions.

After the pretest, the curricula subjects were taught by the teacher using the same pedagogical strategies. After the classroom lessons, students of ICIA, ICGA, and OCIA interacted with the DER. The interaction with the DER took place during three classes of 90 min each, in three different weeks and was accompanied by exploration guides, in order to enhance the relationship between the software and the features which were abler to lead to specific educational experiences.

The students of the CG engaged in pen-and-paper consolidation activities about the addressed subjects, as homework, exploring exercises and problems from their text books.

3.4 Analysis

We inserted and analyzed data in SPSS (Statistical Package for the Social Sciences, version 25). Analyses consisted of variable descriptives (mean and standard-deviation, Cronbach alpha (scale reliability) and Mixed General Linear Model (GLM). Given the reduced *n* of the sample, results must be read with caution and always considering that drawback.

4 Results

As we can see in Fig. 4, there is a general trend of improvement from the pre- to the post-test in all the conditions.

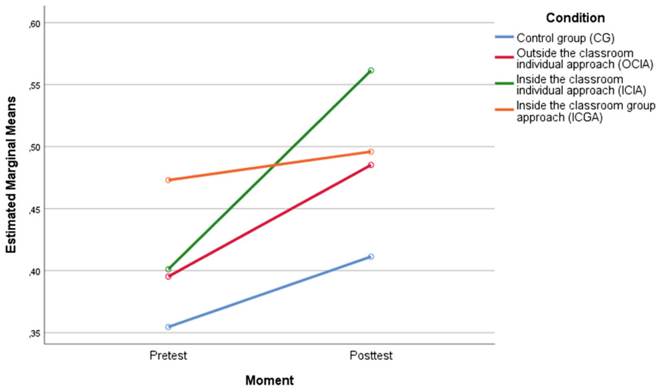

Fig. 4. Mixed GLM with moment as a within-subject factor and condition as between-subject-factor.

In a mixed GLM with moment as a within-subject factor and condition as between-subject factor (with four levels: control, outside the classroom individual digital-based approach (OCIA), inside the classroom individual digital-based approach (ICIA), inside the classroom group digital-based approach), there was a main effect of pretest-posttest, $F(1,57) = 13.77$, $p < .001$, $\eta_p^2 = .20$. The predicted interaction between pretest-posttest and classroom condition was not significant, $F(3,57) = 1.43$, $p = .24$, $\eta_p^2 = .07$, *n.s.* (Fig. 4).

Nevertheless, simple mean comparisons of the moment for each combination of condition showed that the difference between pre and posttest was significant in the OCIA ($M_{diff} = -0.90$, $SE = 0.37$, $F(1,57) = 5.82$, $p = .02$, $\eta_p^2 = .10$), ICIA, ($M_{diff} = -0.16$, $SE = 0.05$, $F(1,57) = 10.17$, $p = .002$, $\eta_p^2 = .15$), but not in CG ($M_{diff} = -0.06$, $SE = 0.04$, $F(1,57) = 2.20$, $p = .14$, $\eta_p^2 = .04$, *n.s.*) nor in the inside classroom group approach ($M_{diff} = -0.02$, $SE = 0.05$, $F(1,57) = 0.21$, $p = .65$, $\eta_p^2 = .004$, *n.s.*) (Fig. 4). These results suggest that the conditions OCIA and ICIA were more effective in supporting students' learning.

Bearing in mind that when we are comparing different student's groups with a CG, it's necessary to be aware that third factors could influence the experience (e.g. type of activities, teacher support, groups differences, etc.), however, simple mean comparisons of the condition for moment levels showed that in the pretest, the only difference between levels of the condition is between the CG and the ICGA ($M_{diff} = -12$, $SE =$

0.04, $F(3, 57) = 3{,}67$, $p < .02$, $\eta_{p}^{2}. = .16$) For the post-test level, a marginal difference between CG and ICIA levels of the condition was found, ($M_{diff} = -15$, $SE = 0.06$, $F(3,57) = 2.50$, $p < .1$, $\eta_{p}^{2}. = .12$.

5 Discussion

In this study, we aimed at testing the hypothesis that DER supported by exploration guides contribute more effectively than pen-and-paper consolidation worksheets to students learning. Furthermore, the effects of each DER in students' achievement. Regardless of the importance of carrying out more research in order to know more about perceived usefulness of DER, enjoyment or students' motivation, in doing this research about the learning effects of four different teaching approaches, we shifted from these perceptions to the effective support in learning given by DER.

Results showed a significant improvement in the targeted chemistry learning outcomes, thus, partially supporting the hypothesis that DER would be more effective than pen-and-paper consolidation worksheets. In fact, the effect of working with DER individually either inside or outside the classroom is statistically higher. In addition, even though we were able to see positive differences between pre and posttest in all conditions, we found a marginally significant difference in the posttest between the control condition and the inside the classroom individual approach.

In spite of considerable change in the technological landscape in schools and in society that took place in the last decade, one-to-one computing is the exception rather than the rule in research reports about multimedia in science education [26, 27]. What is hindering the adoption of one-to-one computing? The reason for this situation may lay in the co-constructive conceptualization of the learning process, which is appreciated by teachers, but also in the allegedly lack of equipment. Claims about the need to radically transform education, as they evoke extreme arguments, may be spreading a kind of moral panic, building new barriers between teachers and students, supporters of technology and non-users [28].

Common sense representations about the scarcity of resources and the obsolescence of the digital park may also inhibit (or justify) teachers' scarce usage of this one-to-one computing strategy. Nonetheless, we must acknowledge that, except for the resources developed by publishers, there is a lack of computer simulations and animations for science teaching in Portuguese language. As [29] suggested, the very own affordances of the Internet, namely in what concerns the authority and stability of the contents, ask for reform-minded teachers, who are capable to cope with an increasingly complex world.

Based on this study, we propose a soft transition towards the usage of technology rather than disruptive strategies. Given the pressure felt by teachers, the integration of DER should comprehend the multiple understandings about the role of the teacher, the curricular framework and the needs of students.

In the present case, DER were used to help students' consolidating their knowledge about chemistry. In other words, they were used as complementary rather than as self-sufficient tools. Furthermore, they were associated with exploration guides, which aimed at helping students focusing on the chemistry content and take full advantage of the digital resources.

DER also open a window to expand educational possibilities when they are used outside the classroom. This is not without difficulties. For example, the students' perception of the legitimacy and usefulness of DER must change. Reference [30] revealed students are more likely to consider Internet useful for unimportant assignments but unreliable. It is thus important that teachers contribute to increase the legitimacy of Internet, in general, and DER, in particular, by identifying valuable resources, giving feedback to students doubts about the resources they find and, ideally, peer-reviewing contents online.

Acknowledging this need, we recently created an affinity space for science teachers. In mCiências [mSciences], teachers can present their own teaching experiences, identify resources and comment on each other's contributions [31]. In doing this, teacher will be more capable to promote the usage of DER as cognitive tools [6] and also epistemic tools. With the support of teachers, DER allow for various epistemic uses, such "scientific reasoning, prediction, theory construction, concept formation and design of other artifacts, instruments" [32].

Finally, several factors may explain the results of the inside the classroom group approach. Exploration guides, structured as they were, and the DER themselves might favor a design more targeted to individual than group dynamics. On the other hand, the difficulties that students usually express in the management and organization of collaborative work may also have contributed to the less positive performance in that group condition.

Even if using the ICT and working in small groups can affect in a positive way the learning outcome, it is important to be aware of the fact that positive influence does not depend only on the way that the students work – in a group or individually. There are educational and contextual factors which may attenuate the influence of the social context, both in what concerns group performance and individual. For example, the type of technology used, student's experience in using computers and in cooperative learning strategies, the design of the tasks, the size and the composition of the group, and the experience and training of the teacher.

6 Conclusion

The fact that chemistry deals with abstractions and several phenomena in microscopic level is one of the main reasons why this science is so particularly difficult for the students, especially for those younger students who are starting to learn science. As a result, many of them fail to achieve a sustained and deep understanding of the different concepts. Thus, the use of DER can contribute to an education process more focused on the student, taking into account the differences between the individual learning processes and rhythms, the appropriateness of the concepts to the personal skills, and providing to the students tools that might promote the development of their cognitive skills.

It should be noted that the results from the students who interacted with the DER outside of the classroom environment, seem to suggest that these resources have the potential to be integrated into educational experiences beyond the school environment, thus encouraging students' autonomy, accountability and self-regulated learning skills. These skills are especially valuable for better integration in today's society and for triggering more and better questions and reflections to be shared among the large group in the classroom.

More than the reduced number of participants in each condition that limited this research, it is important to emphasize that the current results must be considered within the complexity of educational scenarios where is hard to identify simple causal explanations.

Although we have used a quasi-experimental design – that in its genesis implies defining a true causal relation (cause-effect relation) - given the great complexity of human beings and the large number of variables involved in the dynamics of the educational process, and whose total control seems very difficult, if not impossible, we cannot assert in a totally peremptory and unequivocal way that a possible improvement in student performance is due exclusively to their interaction with DER.

Another crucial point that needs to be highlighted is the fact of this research answered – at the time – an evident gap in the Portuguese science teaching and learning landscape as it lacked digital educational resources. Additionally, the simplicity of the research design may be easily adopted, therefore, allowing for comparison of results. Given the time elapsed between the data gathering moment and the present day, it would be helpful to conduct new studies about affordances of the different approaches and how teachers perceived, question and perhaps adjust their role throughout the process of integrating DER in their teaching practices.

It is about time to realize the gap between deterministic views on the effectiveness of technology and the actual evidence coming from school settings. We urge for a critical evaluation of the assumptions underpinning discourses about the educational value of technologies so that more than beneficial tools, we can take them as epistemic tools. Such challenge, however, is not reserved for students. It asks for teachers. Through the integration of DER inside the classroom, as they overview, support and expand students learning, teachers may also test their own assumptions about the way students interact with technology. This is paramount if only we remember how interconnected technology and science are today. Only by adding evidence about teaching practices and continuously interpreting their meaning we can hope for better science education.

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Comparing the Effectiveness of Using Tablet Computers for Teaching Division to Kindergarten Students

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Abstract. The present study aimed to assess the effect of the use of tablet computers in teaching division to kindergarten students. Our research compares the level of mathematical competence of the students taught using our tablet oriented learning method which specifically takes advantage of 'Realistic Mathematics Education' (RME) for the concept of division, as opposed to traditional teaching methodology. The software was designed to follow the RME theory. The present study used one experimental and one control group. We found that the students who were taught with educational intervention with the use of tablet computers and the RME theory had a significant improvement on their understanding of division in comparison to those taught using the traditional teaching method. The teaching of Mathematics for kindergarteners using tablet computers has emerged as a vital area of study and academic research.

Keywords: ICT · Realistic Mathematics Education · Division · Kindergarten

1 Introduction

The integration of Information and Communication Technologies (ICT) into kindergarten education has become a high priority for all those involved in the learning process [1–3]. An increasing body of literature provides more and more evidence to the effectiveness of the use of information technology to facilitate teaching and learning processes in various school subjects [4–8]. Particularly, studies have demonstrated that computers have supported the development of the abilities in children's memory, problem-solving, literacy and math [9–16]. These technologies can therefore play an essential role in achieving the objectives of the kindergarten curriculum in all sectors and subjects if supported by developmentally appropriate software applications [17–20] embedded in appropriate educational scenarios [21–23].

Integrating digital technologies in ways appropriate for instructing students in the field of mathematics is not new [24]. For over three decades, digital technologies have been part of mathematics educators' array of tools, knowledge, and processes used to enhance engagement and understanding in learning and teaching processes [25, 26]. Research focusing on the proper use and incorporation of technology in early childhood education has shown that the use of the ICT can bring forward great improvements to

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student engagement, motivation, confidence, curiosity and attention [5, 27–33] even with preschoolers with concurrent risk for mathematics difficulties [34].

Thus it becomes obvious that a very attractive environment of investigating the use computer in education of mathematics emerges in the kindergarten level.

2 Rationale

In the most ideal setting, Information Communication Technologies are treated as a tool for teaching and learning alike [34–37]. They are used as a tool for the students to become more familiar with new technology and to integrate investigation, communication and understanding across the full range of the curriculum.

The advantages of using mobile devices in student learning are quite enormous. The biggest advantages of using mobile devices are to provide student-oriented teaching and learning contexts where the learning of the students generally depends on their active involvement [38]. One of the pressing issues that make this technology a potential for teaching-learning purposes is the increasing usage of mobile devices among the younger generation [39]. Many researches have found that mobile computers can modernize assessments and provide students and teachers with more substantial indicators of progress. Mobile applications can also make educators more efficient by automating the auxiliary tasks of implementing an assessment [40].

Teachers can play a key role in implementing the new technologies in the classroom [41]. Teachers' perceptions about the impact of mobile technology in teaching reflect their beliefs about how technology affects the learning process [42, 43]. The heart of the problem are traditional obstacles faced when integrating technology such as the instructor's educational level and experience, gender and age, experience with technology in educational environments and their general views and attitudes toward computers and there use can greatly influence the integration of technology into the classroom environment [43]. These obstacles may also stop instructors from developing the knowledge, pedagogy, and self-awareness necessary to move past "low levels" of technology integration and enable teachers to take full advantage of the instructional benefits that technologies provide [38].

Various researches' results relate the appropriate use of computers with the ability of students to more efficiently understand the different mathematical notions [14, 44–47]. Also, a vast number of studies show a positive interrelation between the use of computers and the development of mathematical thinking in early years [5]. Nonetheless, computer based activities should reflect the theoretical ideas behind them [2, 38, 48].

Technology no longer refers to computers [28]. The use of touch screens has exploded over the last decade and children have become the earliest adopters and major consumers of touchscreen devices [49–51]. Smart mobile devices, such as tablets, have made a dynamic entry into education, especially in childhood. The use of tablet technologies in mathematics certainly seems enticing [52]. Tablets with multi-touch technology have the potential to foster important aspects of child development of number awareness [53] and at the same time may provide the opportunity to address some of the traditional obstacles such accessibility difficulties [29]. Compared to traditional peripheral devices, the usage of touchscreens is completely based strictly on touch or interactivity [54] as well as their high ease of use, relatively low cost and accurate, digital measurement abilities which provide everything needed to successfully conduct cognitive experiments with young children [55]. Research indicates that young children may be able to make significant gains in numeracy performance in a short period of time while interacting with digital applications [56]. Results showed that there are positive long-term effects when children learn to use a touch-screen device at an early age [57].

The importance of mathematics training in the childhood years has gained increasing attention worldwide, as researches show that significant changes in mathematics education in kindergarten through the first grade are a powerful precursor to future academic and economic success [20, 30]. Early mathematics difficulties lead to long-term educational problems. Knowledge of mathematics in early childhood assists later reading achievement.

Research in early childhood mathematics education highlights its importance; young children working in appropriate educational and pedagogical environments have the potential to develop remarkable mathematical ideas. Quality mathematics in the kindergarten level should be a joy, not a pressure under the assumption that mathematical activities do not involve forcing elementary arithmetic onto younger children [5]). However, even today, children learn mathematics through traditional approaches, namely through math lessons that are often presented as separate activities, either unconnected to the mathematical concept, or they only loosely adhere to mathematical topics. As a result, in most early childhood classrooms, counting from 1 to 20 is often seen as a boring drill and is usually considered a difficult task. Moreover, traditional mathematical activities, carried out by marking the right answer on a workbook lead children to consider that mathematics is not attractive. Children's interests and play should be the source of their first mathematical experiences and a classroom environment that contains mathematics-related objects can help children recognize and apply mathematical knowledge [5].

To overcome such disadvantages of traditional teaching, the software designed and the students' activities developed and examined for the purposes of the current study were inspired by the framework of Realistic Mathematics Education. RME is an active and constantly evolving theory of teaching and learning mathematics [58, 59]. Indicative of this, the learning and teaching trajectories with intermediate attainment targets were conducted for the subject of mathematical calculation at kindergarten level [60, 61].

In the whole trajectory of the RME's teaching theory, the division can be seen as a repeated subtraction. However, following the broad exploration of multiplication, the division is manifested as a shorted calculation and as inverse multiplication. Additionally, in RME board conceptual exploration through elementary context problems begins with a "times" or "repeated addition" structure. Also, division can take on the following appearances in context of three levels:

- First level: line structure. This is a number line, e.g. numbering, distance, time, chain, strip, etc.

- Second level: group structure. These are groups of various types, e.g. bags, boxes, etc.
- Third level: rectangular structure. This is a rectangular pattern, e.g. tiled floors of blocks, trading stamp cards, weave patterns, grids, etc.

These should be the main focuses of the learning and teaching procedure concerning division in kindergarten level.

Following the theoretical framework that blends together Realistic Mathematics Education (RME) and the use of ICT in kindergarten, we designed a new model referred to as the Kindergarten Tablet Division Model (KTDM) which consisted of three levels. The majority of previous studies aggregately examined the effects of various teaching on mathematics. However, a small number of studies have found in the kindergarten level in the area of division.

Our study was based on the above mentioned international literature; we set out to investigate the following research question:

- The kindergarten students who will be taught division with educational intervention based on KTDM will have a significant improvement in comparison to those taught using the traditional teaching method.
- The low and medium levels of kindergarten students who will be taught division with educational intervention based on KTDM will have a significant improvement in comparison to those belonging to high level students.

3 Methodology

The present study was conducted in three phases. In the first and third phases, the pre-test and post-test were given to the students respectively. In the second phase, the teaching intervention was performed. The study was carried out during the 2016–2017 school year in seven public kindergarten schools located in the city of Rethymno on the island of Crete. It was an experimental research which compared the ICT teaching process to traditional teaching based on the kindergarten curriculum. The sample included 119 kindergarteners consisting of 57 girls and 62 boys aged four to six years old. There were two groups in the study, one control (n = 60) and one experimental (n = 59). In the control group there was not a computer available for the students to use. The classes in the experimental group had tablet computers available for daily use by children as part of the teaching procedure. For the uniformity of the survey, instructions were given to the kindergarten teachers who taught in the experimental or control groups.

3.1 First Phase

In the first phase, the pre-test was given to the classes of the experimental and control groups during the beginning of December 2016 to isolate the effects of the treatment by looking for inherent inequities in the mathematical achievement potential of the two groups. The pre-test was a test based on the Test of Early Mathematics Ability third edition, TEMA-3 [62].

The TEMA-3 is a norm-referenced, reliable, and valid test of early mathematical ability that is appropriate for children of ages 3 years and 0 months through 8 years and 11 months. The form of TEMA-3 contains 72 items. The purposes of TEMA-3 are to: (a) identify the children who are significantly behind or ahead of their peers in the development of mathematical thinking, (b) identify specific strengths and weaknesses in mathematical thinking, (c) suggest instructional practices appropriate for individual children, (d) document children's progress in learning arithmetic and (e) serve as a measure in research projects. Also, one of the purposes for developing the TEMA-3 was to provide researchers with a statistical test that was based on current research and theories about mathematical thinking. In particular, TEMA-3's availability would stimulate the study of mathematical thinking in young children [62].

Due to the young age of the students the pre-tests were administrated individually to each student like an interview. These were pencil-and-paper tasks in which the students were asked to share objects into a set of groups or to divide objects by drawing a line among them (Figs. 1, 2). Each task had a grade that was computed from the student's answers. Scores were computed for each of the individual mathematical tasks. The total correct responses for each of the twelve tasks were produced by adding the all correct responses of each problem on that task. On average, students will be able to complete the relevant portion of the test in about 20 min.

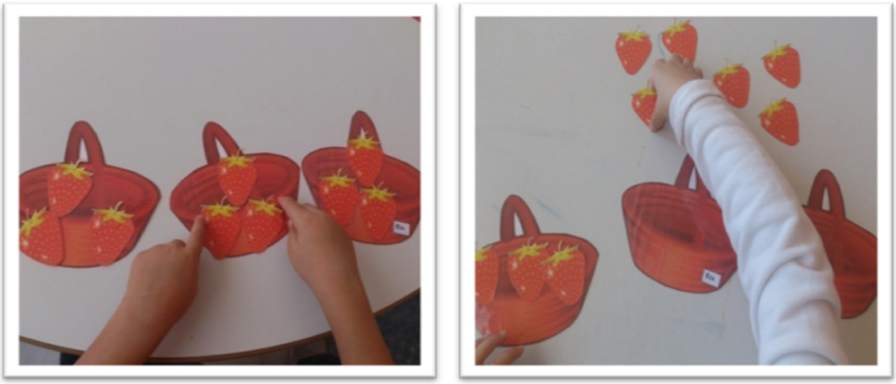

Fig. 1. The student has to divide the strawberries among the three baskets.

3.2 Second Phase

In the second phase, the control group taught with traditional teaching according to the kindergarten curriculum. Group and individual activities were given to children every day. The experimental group covered the same material at roughly the same time according to the KTDM procedure. The content of the three week syllabus of the KTDM was divided into three levels. Each level has tablet computer and non-

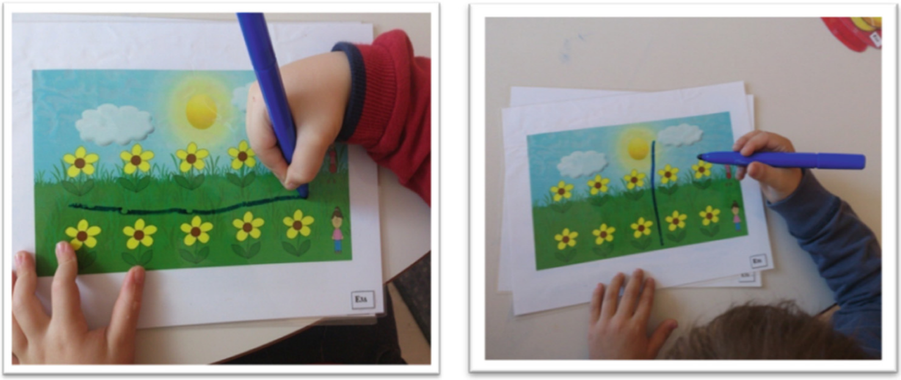

Fig. 2. The student has to divide the ten daisies into two equal parts by drawing one line.

computer activities. The tablet computer activities were designed using Flash CS6 Professional Edition.

The first level started with an activity of the line structure. The objects were placed on a line and the students had to divide them among two or three persons. For example, Peter's and Maria's grandfather put some apples on the line and wanted to share them between the two grandchildren (Fig. 3). The kindergarten teacher asked students: "How many apples do they have? How many apples will every child get?" Then a tablet computer activity with division problems took place in which there were two builders and they wanted to build a road with hearts. The road had two parts. They must to put an equal number of hearts on each section of the road (Fig. 4). The tablet computer program asks questions like: "How many hearts are there in total? How many hearts must be on each section of the road?"

Fig. 3. Non-computer activities with apples (line structure).

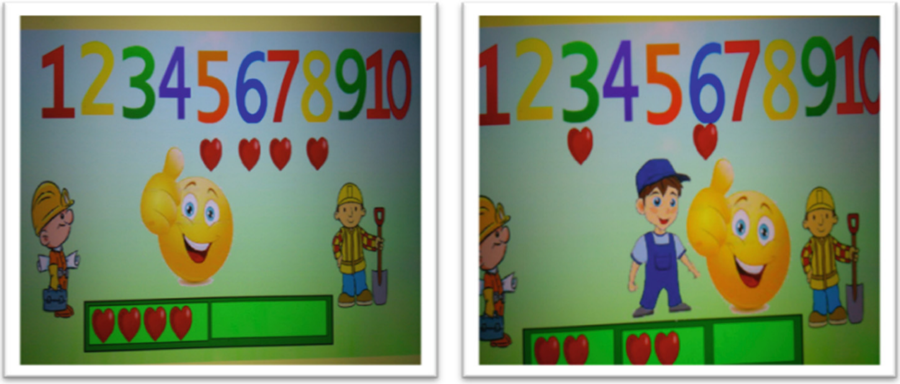

Fig. 4. Tablet computer activities with the road of hearts (line structure).

The second level started with an activity of the group structure. The kindergarten teacher gave some apples to John in a ball. Then John equally divided the apples into two bags (Fig. 5). The kindergarten teacher asked John: “How many apples do you have to put in each bag?” Finally, a tablet computer activity took place with division problems. For instance, Mary wanted to make two bracelets with buttons and had six buttons (Fig. 6). The instruction from the tablet computer was: “Drag and drop the same number of buttons in each circle.”

Fig. 5. Non-computer activities with apples (group structure).

The third level of the teaching procedure started with an activity of the rectangular structure. The students played the “curtain” game. Initially, students were given curtains with various designs with fish, circles, triangles, squares, etc. The students were asked to cut the curtain with the scissors in two equal parts (Fig. 7). Then the kindergarten teacher asked a group of questions: “How many fish does your curtain have? How many fish will each piece have?” After each correct answer, the student was

Fig. 6. Tablet computer activities with bracelets (group structure).

expected to point to, read and write the correct number. The final part of this level involved a tablet computer-based group activity. First, two boys and a field with eight cherry trees appear on the tablet computer's startup screen. Then, the student is asked to separate the field with the cherry trees in two parts by moving a green line across the screen, in order to split the trees between the boys equally. Then the student must answer a group of questions prompted by the tablet: "How many cherry trees are there in total? How many boys shared the cherry trees? How many cherry trees does each boy have?" Click the correct number (Fig. 8).

Fig. 7. Non-computer activities with curtains (rectangular structure).

3.3 Third Phase

Similarly, during the third and final phase of the study, after the teaching intervention, the same test was given to all students in both the experimental and control groups as a post-test at the end of March 2017 to measure their improvement on division.

Fig. 8. Tablet computer activities with cherry trees (rectangular structure).

4 Results

Analysis of the data was carried out using the SPSS (ver. 21) statistical analysis computer program. The independent variable was the group (experimental group and control group). The dependent variable was the students' post-test score.

4.1 Evaluate the Effectiveness of Using Tablet Computers for Teaching Division to Kindergarten Students

The first analysis was a t-test among the students' pre-test scores of mathematical achievement for division in order to examine whether the experimental and control group start from the same level. There was a significant difference in the students' pre-test scores for experimental ($M = 5.983$, $SD = 1.293$) and control groups ($M = 6.866$, $SD = 2.813$); $t(117) = -2.195$, $p = .030$ Tables 1 and 2. As a result, an ANCOVA analysis will be processed.

Table 1. Group statistics of pre-test.

Group	N	Mean	Std. dev.	Std. error
Experimental	59	5.983	1.293	.168
Control	60	6.866	2.813	.363

Before conducting the analysis of ANCOVA on the students' post-test scores for mathematical achievement for division to evaluate the effectiveness of the intervention, checks were performed to confirm that there were no violations of the assumptions of homogeneity of variances (Pallant 2001). The result of Levene's test when pre-test for mathematical achievement for division was included in the model as a covariate was not significant, indicating that the group variances were equal, $F(1, 117) = 0.157$, $p = .693$; hence the assumption of homogeneity of variance was not been violated.

Table 2. Independent samples test of pre-test.

Pre-test	t	df	Mean difference	Sig. (2-tailed)
t-test	−2.195	117	−0.883	.030

After adjusting for scores for mathematical achievement for division in the pre-test (covariate), the following results were obtained from the analysis of covariance (ANCOVA). A statistically significant main effect was found for type of intervention on the post-test scores for mathematical achievement for division, $F(1, 116) = 333.571$, $p < .001$, Partial Eta Squared = .742 (Table 3); thus the experimental group performed significantly higher in the post-test for mathematical achievement for division than the control group.

Table 3. Comparison of student scores for mathematical achievement for division in post-test: ANCOVA analysis.

Sources	Type III sum of squares	df	Mean squares	F	Sig.	Partial eta squared
Pre-test	186.559	1	186.559	150.075	.000	.564
Group	414.664	1	414.664	333.571	.000	.742
Error	144.200	116	1.243			

4.2 Evaluating the Stratification of Students in Mathematical Achievement for Division After the Teaching Intervention According to Their Success in Pre-test

Moreover, a stratification of experimental and control group according to their success in basic stereometry concepts of the pre-test was divided into three equal categories: less than 5.1 (35.3th percentile - low), 5.1 to 7 (35.3th to 70.6th percentile - medium), and more than 7.1 (70.6th percentile - high). In the 64 including both groups (i.e. the experimental and the control group) before teaching intervention.

The Table 4 shows that 29.4% of the students of the both group exhibited high grading, 35.3% exhibited medium grading, whereas 35.3% exhibited low grading.

Table 4. Frequencies of the two groups in pre-test of general stereometry achievement.

Pre-test	Experimental and control group	
Grading	*N*	*f%*
Low	42	35.3
Medium	42	35.3
High	35	29.4
Total	119	100.0

A two-way ANOVA was conducted that examined the effect of group (experimental versus control) and the students' level of mathematical achievement (low versus medium versus high) on their improvement on division (post-test minus pre-test score). There was not a significant interaction between the effects of group and mathematical level on students' according to their success in division, $F(2, 113) = 2.472$, $p = .089$, Partial Eta Squared = .042. On the contrary, the effect of mathematical level was significant $F(2, 113) = 33.147$, $p < .001$, Partial Eta Squared = .370, with the improvements of mathematical achievement in the low and medium levels were higher (low- M = 1.000, SD = 6.381, medium - M = 4.533, SD = 1.357) than those in the high level (M = 3.875, SD = .353) after the teaching intervention (Table 5, Fig. 9). Also, the effect of group was also significant ($F(1, 113) = 361.329$, $p < .001$, Partial Eta Squared = .719), with children in the experimental group scoring higher (M = 5.101, SD = 1.505) than those in the control group (M = .916, SD = 1.393) after the teaching intervention.

Table 5. Mean and standard deviation of mathematical improvement in division according to the levels of mathematical achievement of the pre-test.

Level	Class	M	SD	N
Low	Experimental	6.381	1.023	21
	Control	1.952	1.359	21
	Total	4.166	2.536	42
Medium	Experimental	4.533	1.357	30
	Control	1.250	1.055	12
	Total	3.595	1.963	42
High	Experimental	3.875	.353	8
	Control	−.037	.807	27
	Total	.857	1.817	35
Total	Experimental	5.101	1.505	59
	Control	.916	1.393	60
	Experimental	6.381	1.023	21

The Bonferroni post hoc tests indicated that students' improvement in division of the experimental group of the low-level and medium-level groups differed significantly from students' improvement of the high -level group ($p < .001$ for low-level and medium-level).

Results of this study expand the research on the effects of appropriate software embedded in a computerized environment as a tool for mathematical reasoning used alongside with specially designed activities [3, 8, 15, 16, 23, 44, 45, 48, 59, 61]. Also, the outcomes of the present study create a new teaching model with tablet computers and non-computer division activities on the theoretical framework that were combined with Realistic Mathematics Education in the kindergarten level.

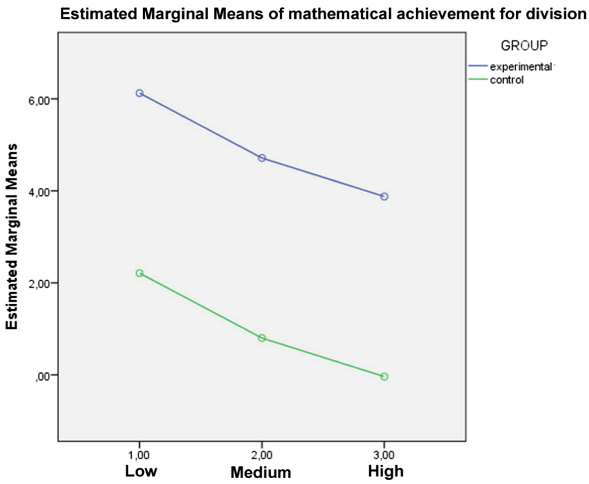

Fig. 9. Mathematical improvement after the teaching intervention according to the levels of mathematical achievement for division of the pre-test.

5 Discussion

The general purpose of the study was to investigate the impact of instructional intervention using the Kindergarten Tablet Division Model for the purpose of teaching the mathematical concept of division in regards to the mathematical competence of the kindergarten level students. In this research, we found that the students that were taught with educational intervention based on KTDM had a significant improvement on their mathematical achievement of division in comparison to those taught using the traditional teaching method according to the kindergarten curriculum. Our findings agree with similar researches [12, 14, 37, 61] which implied that ICT helps students to understand mathematical notions more effectively. As a result, the first research question answered positively.

Also, our findings suggest that students belonging to the low and medium levels of mathematical achievement, who were taught division with educational intervention based on KTDM had a significant improvement, compared to those belonging to the high level of mathematical knowledge students who were taught with the same method. Our outcomes overlie with the results of other similar studies which indicate the positive effects of a computer based teaching model for mathematical notions [2, 23, 33, 37, 46, 47]. Thus, the second research question was addressed.

Regarding the educational value of the present study, its findings should be taken into account by a range of stakeholders such as students, teachers, researchers and curriculum designers. Specifically, our designed teaching approaches could be set up as a broad range study in order to examine to what extent they help children understand division. We as instructors of educators will certainly try to inform our students about these results, which they will need to keep in mind when designing activities for children. Moreover, the learning method based on Realistic Mathematics Education

(RME) using ICT can interfere in various mathematical subjects as a research plan. The result of this research can be extended by developing various similar studies in geometry and mathematics in kindergarten and the first classes of primary education.

The above discussion should be referenced in light of some of the limitations of this study. The first limitation of the study is that the data collected was from the participants residing the city of Rethymno on the island of Crete. The second limitation of the study is that the data collected was from a very small sample (119 kindergarteners). However, as the study was of small scale and context specific, any application of the findings should be done with caution.

Taking into account the above discussion of this work, we argue that the tablet-computer-supported learning process is an ongoing challenge for the reflective teacher to decide on how this technology can best suited for kindergarten students.

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Oscilloscope Reading Device for the Visually Impaired

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Abstract. The purpose of this paper is to describe an assistive technology solution to the problem of allowing visually impaired individuals to use an oscilloscope in an electronics laboratory setting. More specific, a stylus device was implemented with which the person will scan the oscilloscope's surface. This device interacts with the user via sound and vibration to indicate the location of the signal of interest. By sliding the stylus over the screen, the user can visualize the depicted shape, locate the waveform's peaks and take approximate measurements of amplitude and period. In general, the device is a low cost, portable solution that will support visually impaired people to participate and understand the lab courses more effectively.

Keywords: Assistive technology · Visually impaired · Oscilloscope · Stylus

1 Introduction

As technology advances, the level of expertise and the demand of specialized education evolve as well. It is typical for students to be exposed to at least one science, technology, engineering, or mathematics (STEM) course during their post-secondary experience. Courses like these often include laboratories and interactive lessons that help students understand the subject more deeply. However, the student community includes a considerate percentage of individuals with disabilities. Adjusting education to meet the requirements of such individuals, thus making it inclusive, requires the elimination of certain obstacles and inequalities. Each case should be dealt differently in accordance to the location, the disability and the psychology of the person [1]. In the direction of making inclusive education possible assistive technology has an important role in providing the individual with the appropriate tools.

In accordance to Mohler [6], assistive technology (AT) is "any item, piece of equipment or product system, whether acquired commercially off-the-shelf, modified or customized, that is used to increase, maintain or improve functional capabilities of individuals with disabilities [2]." Such technology can be utilized in a laboratory setting to enhance these people's ability to understand the experiments. The focus, though, should not be to enable them to independently execute the experiments or operate the machinery but rather to help them understand the results and improve their knowledge. In other words, assistive technology should help educate more effectively and cannot always replace the human assistant.

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In this manner, several attempts have been made towards this direction. Computer accessibility technologies can utilize text-to-audio tools, Braille displays and even GPS technology for orientation. In a lab setting the experiment can be executed on a simulation with appropriate accessibility features, closed-circuit televisions (CCTV) with magnification abilities [3]. Also, research has been conducted on the fields of bottom-up renovating of the laboratory infrastructure (i.e. Accessible Biomedical Immersion Laboratory) [4] as well as cost–effective custom–engineered solutions to overcome specific barriers.

In this paper, the focus will be the visually impaired individuals and their ability to attend an electronics laboratory. More specifically, the main problem we solved is how to help a person with partial or complete visual disability visualize a waveform and measure it on an oscilloscope's screen. In this direction, we introduce a stylus device that interacts with the user via sound and vibration to give information about the exact location of the screen's waveform.

2 Method

2.1 Operation of the Device

Firstly, the device we designed for the cause introduced in the previous section is a stylus-shaped instrument that the user can easily handle and scan the oscilloscope's surface. We separated the whole process into two functions. That is, understanding the shape of the depicted waveform and then taking measurements over it.

For the first phase, the user, to begin scanning the screen, should press the button associated with this function and hold it. The user holding the stylus scans the surface just like drawing on the screen. Every time the tip finds a point of the waveform, a specific tone is produced (Fig. 1). This way the user can identify the shape of the waveform and, eventually, visualize where the peaks of the signal are.

After that, the user, already knowing the location of the peaks, can then measure its amplitude and period by pressing the designated button. The stylus is equipped with a wheel that can be rolled across the distance to be measured. For example, if a

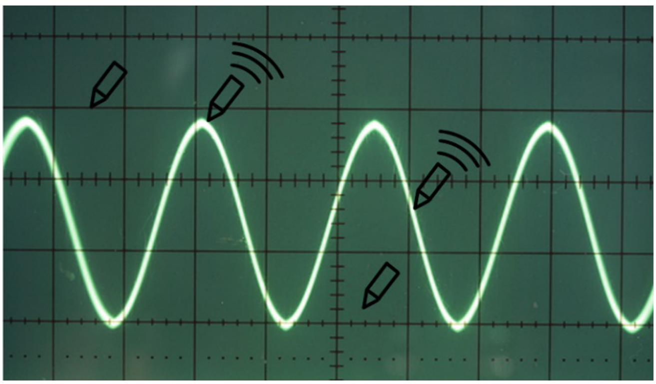

Fig. 1. Illustration of how the location of the screen's waveform is specified.

measurement of amplitude is required, the user should place the wheel on the top peak and roll it until the bottom peak is reached (Fig. 2). Every time the stylus travels one centimeter (or 1 DIV) it produces a short vibration, notifying the user. Next, by multiplying with the appropriate Volt/DIV constant, the approximate value of the signal's amplitude can be calculated. In the same manner, the period is calculated by rolling horizontally across the screen.

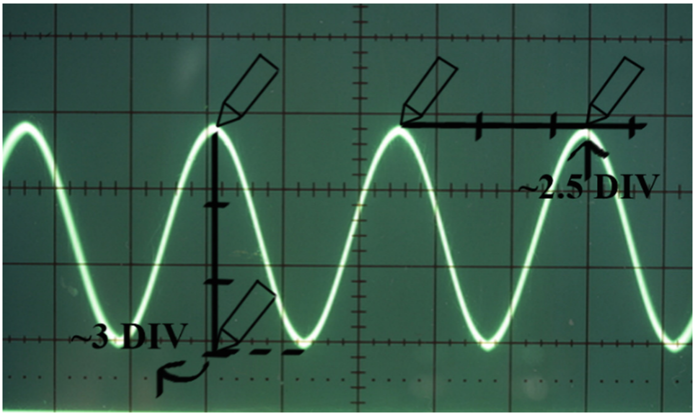

Fig. 2. Illustration of how the amplitude and the period are specified. (Each DIV of distance activates the vibration).

2.2 Implementation

For the implementation of the device we selected an AVR microcontroller (ATMEGA328P) by Atmel. The reasons for this selection are the availability and low price as well as the abundance of open source material. This microcontroller will execute the program and handle the control of the device's circuitry.

The software development was executed on the open software AVRdude using the Atmel's libraries and register descriptions. The atmega328p includes a lot of features that were essential to our project such as Timer/Counter registers, Analog to Digital converters (ADC), Pulse Width Modulation (PWM) outputs, digital inputs/outputs and interrupt service routines (ISR).

2.3 Function 1: Visualizing the Waveform

The first function of the device is producing a sound effect when the photocell receives light from the screen. The photocell's input is an analog voltage that the microcontroller converts into a digital value. When the photocell is on a part of the screen's background, it receives less light resulting in a higher voltage value. When part of the waveform comes by, it receives more light producing a lower value. The microcontroller compares these values, enabling the buzzer's PWM output when needed.

To ensure that the photocell will not take into consideration the radiation present in the room, this problem is handled as follows. The first input is saved and is then compared to the following ones. If the voltage drops by a certain threshold, then the microcontroller is informed whether there's waveform's light present. Also, to reduce power consumption, the microcontroller's ADC is enabled only when the associated button is pressed and disabled afterwards.

2.4 Function 2: Measuring the Waveform

The second function is measuring the distance between two points on the screen. The device is equipped with a wheel of certain diameter. Selecting a diameter value of 0.64 cm we get a circumference of 2 cm. Each DIV on the oscilloscope's grid is 1 cm long. So, a full rotation of the wheel corresponds to 2 DIVs of distance.

The wheel's surface is chosen to be black and there are two interdimensional points marked white as shown in Fig. 3. This way by attaching an infrared sensor we can determine every time one of the marked points pass in front of the sensor. When this occurs, the vibration motor is enabled shortly, informing the user for every DIV of distance the wheel rolled.

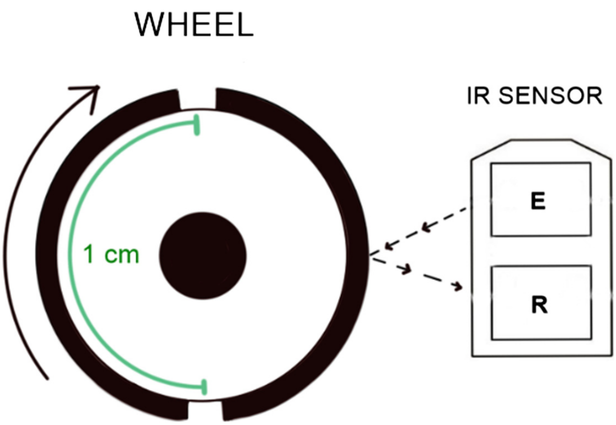

Fig. 3. Illustration of the concept behind the measuring function. (Color figure online)

The logic behind this lies on the fact, that a black surface absorbs more of the sensor's radiation than a white one (Fig. 3). The infrared sensor contains an emitter and a receiver. The light emitted is scattered on the surface of the wheel and part of it reflects to the receiver. The receiver is a phototransistor generating more current when light is present. The color of the surface determines what percentage of the light is absorbed or reflected. For a black surface the absorption is greater, so less light reflects back to the receiver. The opposite is true for a white surface.

The phototransistor's collector voltage is used as input to an external operational amplifier, the LM358, used as a comparator. Its second input is a constant threshold voltage that was chosen experimentally. More specifically, we recorded the voltage across the receiver during a full wheel's rotation (Table 1). Notice that there is a gap between the two states' minimum and maximum voltage. Setting the threshold voltage between values

4 V and 4.5 V, the comparator output is 1 for black and 0 for white surface. This output determines whether to enable the vibration motor's PWM output or not.

Table 1. Infrared Sensor's voltage values for a full wheel's rotation.

Surface color	Minimum voltage (V)	Maximum voltage (V)
Black	4.5	4.7
White	3.7	4.0

The problem that arises is that more than one vibration can occur if the wheel rotates fast. To eliminate this scenario, a delay is forced shortly after each vibration during which the vibrator cannot be enabled. Also, an 8-bit timer register was used to ensure that the delay won't interfere with the other functions of the device.

2.5 Testing the Device

At this point, it is important to evaluate the device's ability to trace the waveform as well as find the most efficient method of operation. For that matter, we recorded users attempting to identify a square pulse and a sinusoidal wave (Fig. 4). The main goal is to

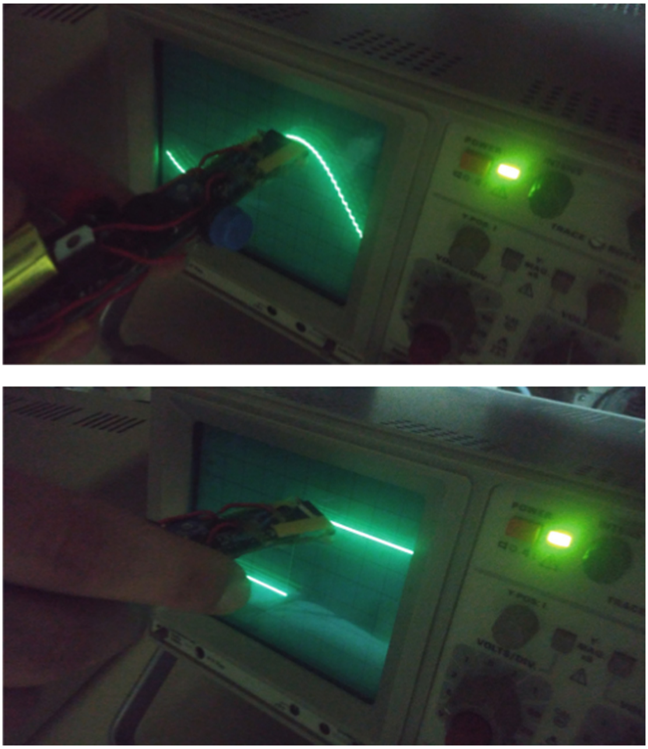

Fig. 4. Identifying a square pulse and a sinusoidal signal using the prototype.

capture the movement of the device while a user attempts to identify the signal. By comparing the different approaches, a certain methodology was determined that allows the user to quickly find the signal's properties by following a specific pattern with their hand. That method is described in the next section.

3 Results

The final circuit (Fig. 5) includes a 5 V voltage regulator (L7805) and is powered by a 9 V battery. The main parts of the circuit include the Infrared sensor's connection with the voltage comparator (LM358M), the photoresistor, the vibration motor, the buzzer and the 10 MHz crystal oscillator. The circuit was manually assembled on a double-sided prototype PCB breadboard 2 × 12 cm (Fig. 6).

For the first function, a voltage value of 0.25 V was selected as the difference threshold described in the method section. This value was selected during tests on a standard analog oscilloscope's screen and can be adjusted in code to match different screen types.

For the second function, we recorded the receiver's voltage during a full rotation of the wheel (Table 1). When a black surface is present, the voltage is 4.5–4.7 V and for the white it is 3.7–4.0 V. Selecting the reference voltage with the potentiometer at 4.1 V, the circuit can detect the two states reliably.

The microcontroller was programmed in C using the AVRdude interface. This software includes the Mfile application which automatically converts the program from C to .hex form and handles the microcontroller's fuses. The connection between the

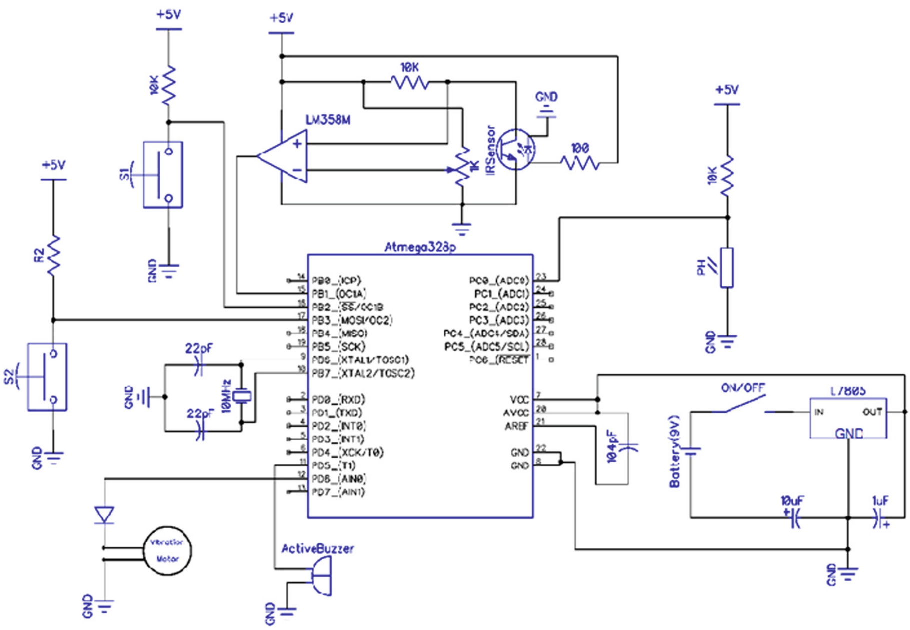

Fig. 5. Representation of the circuit used for the device (designed using PCB creator software).

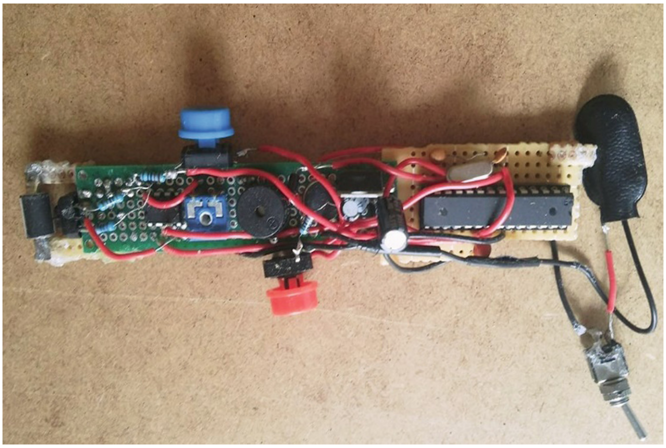

Fig. 6. Prototype of the device's circuit (2 × 12 cm).

computer and the microcontroller, as well as the transfer of the program were executed with the Pocket AVR Programmer by sparkfun [5]. To properly establish communication between the computer and the programmer the libusb-win32 driver was installed. To upload the program on the microcontroller, the computer and the programmer are connected via USB. The programmer connects to the microcontroller as shown in Fig. 7.

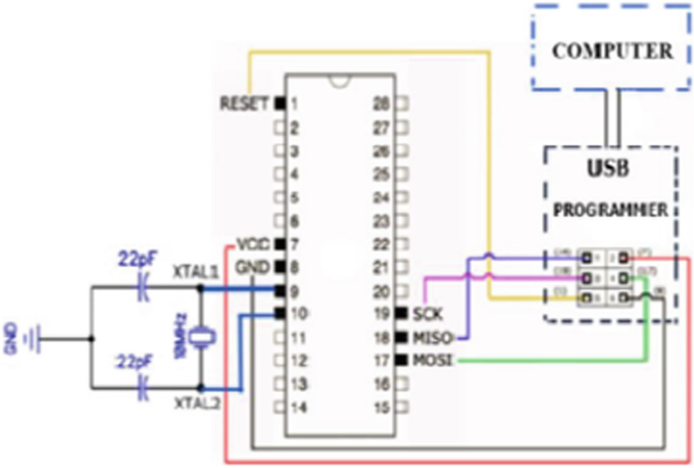

Fig. 7. The connection between computer, USB programmer and microcontroller while uploading the program [5].

The program uploaded on the microcontroller is constantly running in a loop (Fig. 8). This program constantly reads the state of the two buttons for the function selection after a debounce check. The debounce check is a code solution to eliminate any false inputs caused by the switch's "hopping" when it is pressed. Each button enables one of the two functions of the device; the buzzer mode to visualize the waveform and the vibration mode for the measurement.

During the first function of visualizing the waveform, the condition that enables the buzzer is whether the voltage shifted below a certain threshold. To be able to read an analog voltage value, the microcontroller utilizes an internal Analog to Digital Converter (ADC). The ADC runs on 64 prescaling with interrupt enabled. Each time the result of the conversion is available, the code within the interrupt service routine is executed. This code contains the conditions required to enable the buzzer. One thing to consider is that the ADC circuitry consumes power when enabled, and since a conversion is not always required, the circuit must be turned off when not needed. Specifically, when the associated button is pressed, the ADC is enabled, and the first's

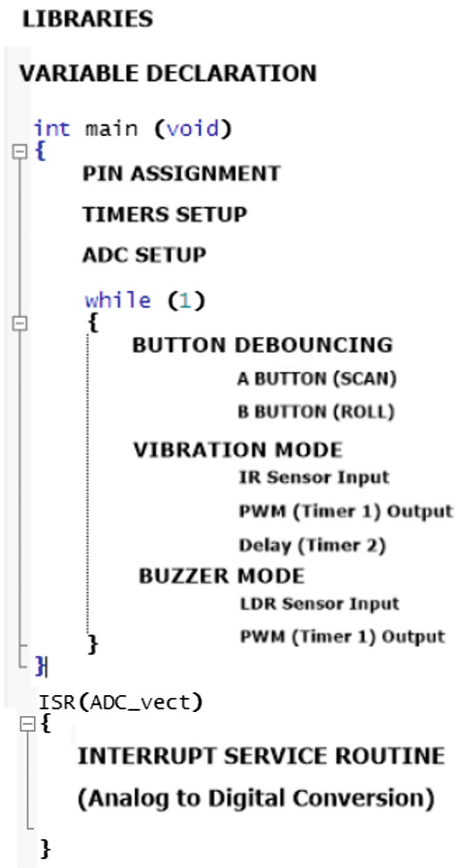

Fig. 8. Brief representation of the microcontroller's executed program.

conversion result is saved into memory. The following results are compared to the first one and when the button is released the program disables the ADC until it is pressed again.

As discussed in the previous section, it is important to introduce a delay between two consecutive vibrations. This delay was implemented using the 8-bit Timer 2 with 1024 prescale. Since the microcontroller runs at 10 MHz, the timer's period is 0.026 s. The value of the Timer's Register is incremented by 1 on each cycle which means that the timer reaches the value of 195 every ~0.02 s. When this occurs, a counter is incremented, indicating how many times the 0.02 s interval has passed. Thus, we can control the timings of the vibrations without completely stopping the program's flow, which is the case for the delay_ms function.

Since the buzzer that was used is an active one, a PWM output is enough to drive it and produce a tone. As for the vibration motor another PWM output was utilized with a duty cycle corresponding to ~3.3 V voltage, enough to produce the desired vibration across the device.

How To Use The Device

As mentioned in the previous section some tests were implemented to define the proper method to identify the waveform with our device. While there are a few possible ways for successful tracking, we selected one specific pattern that the user needs to follow while pressing the associated button. This pattern is shown in Fig. 9 for a sinusoidal signal. The yellow traces indicate the specific movement of the stylus. The red points are where the sound is produced and the dashes where it pauses.

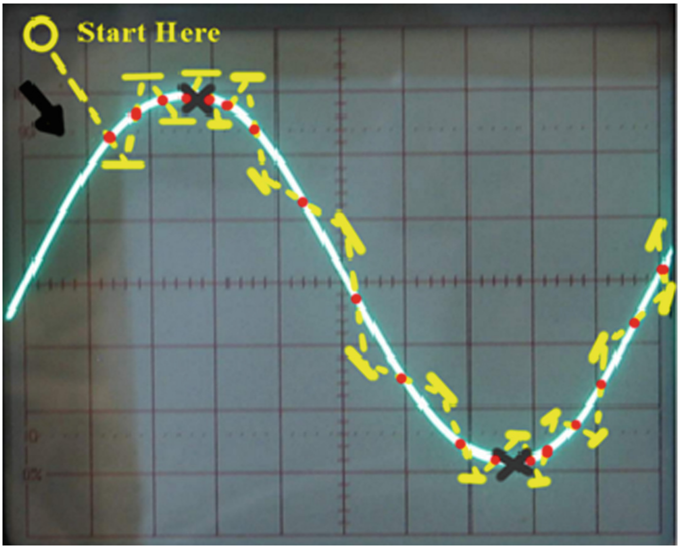

Fig. 9. Example of the stylus' movement while identifying a sinusoidal signal. The traces represent the stylus' movement. The dashes indicate the pauses. (Color figure online)

First, the user is instructed to begin scanning from the top left or right corner to ensure that the first voltage reading of the sensor is on a part of the screen's background. From the top corner the user moves downward and diagonally until the sound is produced. Moving the stylus further will make the sound pause, indicating the precise area that the waveform is on. From there, the user moves diagonally and upwards in the same manner. This way it is easy to understand if the waveform is rising or declining at that specific region. Repeating this pattern will eventually lead the user to the location of a peak. The user is then advised to either hold that spot with the other hand's finger or put a small piece of plasticine on the specific location. These steps need to be repeated until all the peaks are specified. Eventually, the user can indicate the beginning and the end of a period or the zero points if it is possible to set the oscilloscope's GND option on.

While it is easy to determine the rise, or decline of the waveform, it was discovered that the specific shape could not be recognized with such easiness. More specifically, a trigonal and a sinusoidal wave might be harder to distinguish given that they have similar shapes. In such a case the user needs to scan the region near the peaks to be able to specify the curvature. The square pulse, on the other hand, was the easiest to detect given its unique characteristics.

After executing these steps, the user can then further examine the signal by slowly moving the stylus over it on the direction where the sound is on. In other words, the user "draws" the signal by following the sound after its general shape is established.

4 Conclusions

The main goal of allowing a visually impaired individual to attend an electronics laboratory course more efficiently was achieved. The suggested solution was a stylus-shaped device that enables the user to identify and measure a variety of waveforms on the oscilloscope's screen. Although, such a device cannot replace a human assistant completely in an electronic laboratory scenario, it does offer a way for the individual to understand the nature of electronic signals more effectively.

At this point it is essential to address the main constrains of the device and suggest possible solutions. First, regarding the measurement function, the user must manually roll the wheel until a vibration is felt to ensure that a white line is present in front of the sensor. This limitation can be bypassed by equipping the stylus' case with a mechanical structure (e.g. magnets) that holds the wheel on a certain position and releases it when a measurement takes place.

Another constrain is the resolution and error of the measurement. Currently, the device can measure a minimum of 1 DIV distance. Using a bigger wheel with more lines or holes on its surface it is possible to detect even smaller distances. Also, it is possible for the wheel to slide on the screen, if the surface friction is low enough. In other words, the quality of the measurement heavily depends on the quality and the characteristics of the wheel.

Regarding the visualization process, the microcontroller's program can handle scenarios in which the screen's background is darker than the depicted waveform. By improving the algorithm to also work on the opposite scenario (bright background, dark waveform), the device can then be used on any screen display either to identify signals or shapes and graphs in general. This way, individuals can use the device as a universal screen reading tool.

As another interesting approach to the main problem of oscilloscope reading, we suggest one more device. This device is a flat screen extension that the user attaches to the surface of interest (i.e. oscilloscope's screen). The bottom side is equipped with photocells and the upper one with vertically movable metal bars. Each bar is connected to a photocell bellow it and every time it receives light the bar is lifted. Thus, the lifted bars form the pattern of the depicted waveform. In other words, the user can touch the waveform that is textured on the device's surface. While this approach seems more effective there are certain limitations on its mechanical implementation.

Finally, devices like this can be implemented in other aspects of education too. Educators, especially in electronic labs, can encourage their students starting projects towards this direction [2]. This way, students can get important problem-solving experience, deeper electronic design knowledge and familiarize with constrains disabled people cope with. People with disabilities can, on the other hand, guide the projects to the right direction and help make more informative decisions. Having the students collaborate in such a manner will eventually increase the availability of assistive technology solutions in education and lead to more creative, user – friendly devices.

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The Use of Applets in Understanding Fundamental Mathematical Concepts in Initial Teacher's Training

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Abstract. The proper use of virtual manipulatives in the classroom can provide environments that generate a more effective learning in the teaching of mathematics. With these tools, the students receive immediate feedback for their actions, and can conjecture, formulate questions and solve problems in a quicker and more practical way. A mathematics teacher must understand the fundamental principles of a numeral system (FPNS), in order to effectively teaching their first years' students about numbers and arithmetic operations. The work presented here was performed with students from the initial teacher's education and was aimed at analyzing how the applet's use allowed them to acquire a deeper knowledge of the FPNS. This study, of qualitative and interpretative nature and case study design, consisted in the resolution of a set of tasks, with the help of an applet, involving an approach to the FPNS. The results show that, during the resolution of those tasks, with the help of the applet, the mathematical terminology used by the students kept improving throughout the experience. On the other hand, the use of the applet allowed the students to realize the knowledge gaps regarding content involving the FPNS, which were rectified throughout the experience. Therefore, the developed work using the applet and the classroom's practical model in which they were inserted, allowed these students to deepen their knowledge of the terminology used and the content discussed.

Keywords: Teacher's initial education · Virtual manipulatives · Applets · Numeral system

1 Introduction

Technology can play an important role in the classroom and it has been used to improve mathematics' teaching [16]. The students that use appropriate technology are more persistent, enjoy learning more and show improved performance in mathematics

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[9, 14]. More specifically, the investigation shows that the use of virtual manipulatives presents clear benefits, in addition to their complete and free access on the internet [3, 10, 12], its use helps in learning concepts and procedures, significantly increasing the student's mathematical knowledge [5]. It is indispensable that students of the initial education in a Basic Education's graduation course understand the fundamental principles of a numeral system (FPNS), without which they can't, later, develop basic numeral skills. One of those principles it is the place value, which is considered to be the master idea behind all arithmetic [18]. This author highlights the essential importance of teachers understanding that the place value is an inevitable consequence of the way our numeral system works. In [18] is also emphasize that the importance of a deep understanding of the decimal numeral system, in order to understand the arithmetic operation's algorithms and to learn the logic behind them, is a very effective way of acquiring many other fundamental mathematical skills. This study was aimed at analyzing how the use of applets allowed students from the initial education of first years' teachers (from the preschool education to the second grade of Basic Education), to deepen their knowledge about the FPNS. Therefore, it was intended to answer the investigation's key question: How does the use of virtual manipulatives, during the resolution of mathematical tasks, improve the FPNS' understanding of students of the initial education of first years' teachers?

2 Literature Review

The virtual manipulatives, especially applets, are small programs (applications), usually, written in JAVA language, that can be embedded into HTML pages and, therefore, be used through a *browser*. Although its classroom use is still relatively recent, it has been increasing [6] and so has been the investigation about the role and effectiveness of this technology in mathematics' teaching. According to various authors [2, 4, 13, 15], these can be allies in understanding mathematical concepts, being that one of its major characteristics is its immediate and visual feedback, which results from its manipulation [19]. The investigation of the virtual manipulatives' utilization with future teachers is scarce. However, there is a study published by [8] whose focus was the perception of future teachers in using applets to solve problems. In [8], is examined these perceptions in relation with the role and job of the applets, the difficulties the teachers had in using them and their necessity in this specific context. Although most participants felt that the problems could be solved without the applets, they highlighted its role in clarifying the problem and its solution. The participants stated that the applets are tools, which they liked to work with, whereby they were more encouraged to solve problems through their use. In [1], authors concluded that the majority of future teachers stated that the concrete and virtual manipulatives were essential in teaching mathematical concepts, allowing for the discovery of mathematical relations and stimulating the mathematical thought. They also stated that the use of manipulatives would promote the student's academic performance. Therefore, teachers and future teachers need to be motivated, encouraged and trained in their initial or continuous education, in order to use this kind of tool effectively [1]. These concerns and authors investigations' results support the thesis that, a basic education student should, in his initial education, have contact with this kind of technology so that, in the future, he can feel confident and be more interested in using it in his teaching practices, seeing it as an ally in understanding mathematical concepts.

3 Study's Investigation and Context Description

This investigation was developed in a mathematics curricular unit with 22 students from the third grade of a Basic Education course, in a Portuguese higher education institution. Two of the authors, in addition to playing the role of the researchers, were also the teachers of that class. These teachers' professional experience led them to realize the lack of knowledge of their students regarding the FPNS and made them take some measures to resolve this problem. We have to state that, these students, on their academic course, have two curricular units where the FPNS are discussed. Before the intervention, the students answered a questionnaire [11] about their perceptions of their mathematical content's knowledge, and whose individual answers were classified, in average, at level 3, on a scale of 1 to 5.

3.1 Methodology

The nature of this study is an interpretative and qualitative investigation and a case study design [7]. The class' students were grouped according to the Proximal Development Zone's (PDZ) conditions [17] and whose discrepancy optimum levels were established by the results of the questionnaire. For the selection of this report's group, it was chosen the highest average perception of these students about the mathematical knowledge, resulting from the questionnaire's answers. The group is constituted by three students (A, B and C).

3.2 Intervention

The intervention consisted in the resolution of a sequence of tasks (Fig. 1), which involved an approach to the FPNS. In the first session, the task consisted in elaborating the representation of 30 unities, in the bases of 10, 5 and 2. In the second session, it was intended for the students to identify the numbers represented in the applet, in each one of the bases 10, 5 and 2. For each one of these tasks the students should:

(a) mention the objects that they used and why, as well as the reason of the place they were positioned in;
(b) explain how the situation was resolved, step by step, using the proper mathematical terminology;
(c) explain the meaning of the obtained result and its relationship with the answer of the problematic situation.

The tasks were based on the utilization and interaction of the applet *Base Blocks* (http://nlvm.usu.edu/en/nav/frames_asid_152_g_2_t_1.html?from=category_g_2_t_1.html) of the *National Library of Virtual Manipulatives'* repository. This applet's choice was due to the relationship between the mathematical concepts involved and the required procedures in the understand of a numeral system. Throughout the tasks' resolution, the teacher interacted with the students, pointing out questions or clarifying doubts.

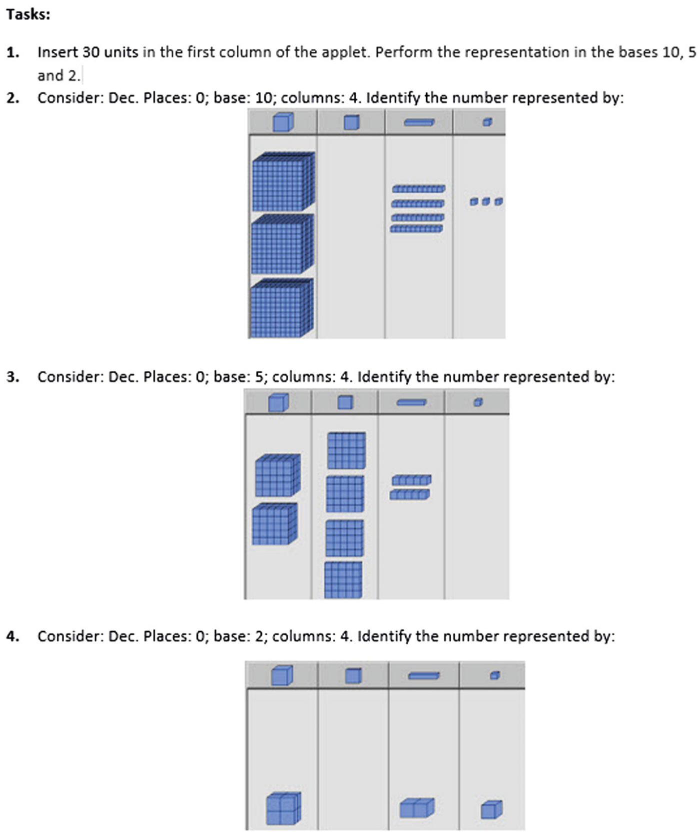

Fig. 1. Applied tasks in the intervention.

3.3 Data Collection

The data collection was performed throughout two sessions, of two hours each, during the school year of 2016/2017, on 30/9/2016 and 6/10/2016. Different sources were used, such as: group and individual written records, performed by the students when they resolved the tasks; the records and observations of the teacher and the logbook of the investigator; the audio and video recordings of the computers' screens where the students worked, using the software FlashBack Express. The larger group discussions were also recorded.

3.4 Data Analysis

Data analysis was performed resorting to crossing of the written records, students' audio recordings and video recordings of computer screenshots of the following items:

- FPNS
  - (i) Organizing in groups with a number of elements equal to the base value.
  - (ii) Place value.
- Mathematical terminology used.

4 Presentation and Discussion of the Results

The group of students revealed difficulties in the FPNS, especially in the place value. The applet helped mapping the frailties of their knowledge, namely:

- FPNS
  - (i) Organizing in groups with a number of elements equal to the base value.

The group had some notion of the grouping concept, in any one of the bases 10, 5 and 2. Early in the beginning of the session, student A said the following:

Student A – That's why it stops appearing here, that is, when you make 10… from the moment you have 10, it no longer appears in this column… when you have base 5, from the moment you have 5 it no longer appears in this column.

However, the group spent a lot of time until they figured out how to join ten units with the applet. Only closer to the end of the session does the following dialogue happen:

Student A – Maybe it's important to state that from the moment we have 10 units we have a ten… it stops being represented.

Student C – but before that… each unit represents 1 unit.

Student A – Each group of 10 units represent one long.

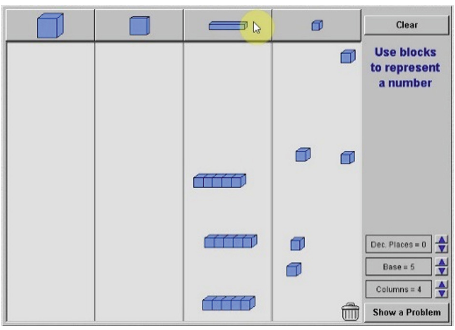

Fig. 2. The student doesn't a group, she just clicks on the long three times.

Student B – … which is worth a ten.

Student A – Because we have 30 units we can represent 3 longs.

The group does not show how they got to the 3 longs using the potentialities of the applet, they just clicked on the long's symbol three times (Fig. 2).

Student C, who always seemed to be the most skeptical and less participative, decides to intervene:

Student C – If you drag this here is it dissolved in 10? – she asks, moving the long from the tens to the units.

Student A and B – No…

Everyone – Aaahhh! – They exclaim when the long ungroups itself automatically in units. (Figure 3)

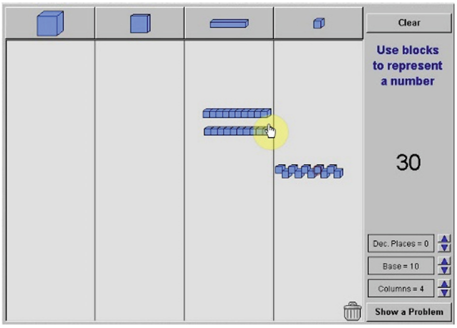

Fig. 3. The Student C discovers how to ungroup with the applet.

Student B – Do it! We've discovered the gunpowder! So now represent the 30 units…

Now the whole group tries to do the reverse process, i.e. the grouping. They cannot, because they do not select the 10 units in the right way.

Student A – The long falls apart… but these don't join – says, while trying, without success, to join the units and then move a unit to the next order.

Student B – But it should work!

The student that was interacting with the applet only did one attempt at grouping the 10 units, however, strangely, did various attempts at changing only one unit to the next column (order). They decide to call the teacher. They explain what they did and state that they cannot make the reverse procedure, but, as the explanation is given, they can do the 10 units selection correctly. They looked surprised. Follows the dialogue between the teacher and the group:

Teacher – What does grouping mean? Can the long stay on the unit's column? Can it stay like this? (positioned in the units' order)

Group – No! – and they drag the long to the tens' order.

Teacher – Why do you have to drag it there?

Student C – Because on the base 10 system, each 10 units on the units' order represent one unit on the tens' order.

Teacher – If I organize 10 units in the units' order I end up building a superior order unit – states the teacher.

The group continues alone. They try inserting the 30 units again, creating, then, two groups of 10 (Fig. 4) and dragging them to the next order (Fig. 5).

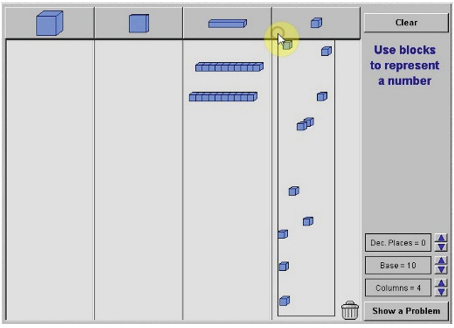

Fig. 4. One of the group's elements performs a 10 units grouping.

Fig. 5. The group builds one superior order unit.

Student A – Now it already appears 30. To each set of 10 units…
Student C – In the units' order…
Student B - We now have a superior order unit.
Student C – Which is represented by one long…
Student A – Which, in this case, is represented by a long… - rectifies.
Student B – Which represents one ten.

It was noted that, after discovering how to perform groupings with the applet, the group felt more confident, even in the way the students were discussing among themselves. They also showed concern in using a more proper terminology, correcting each other when they thought their coworker was not using the appropriate terminology.

(ii) Place value.

About the principle of place value, the group seemed to reveal some knowledge when the base was decimal. We can read the following on their records (task 2, a):

"It were used three units, positioned on the units' order, four longs, positioned on the tens' order and three blocks, positioned on the thousands' order. The three units that are positioned on the units' order are worth three units, considering the numeral system of base 10. The four longs that are positioned on the tens' order are worth four tens units, this is, are worth forty units. In the hundreds' order it wasn't inserted any flat, so its representation is zero. The three blocks that are positioned in the thousands' order are worth three units of thousand, that is, are worth 30 hundred, or 300 tens, or 3 000 units (…)."

However, with a different base, the doubts and uncertainties were much higher than those revealed in the base 10 and they ended up finishing the sessions without being able to finish the tasks, concluding that the value of each unit was altering according to the base. For example, in base 2, each unit is worth 5, as 5 + 5 = 10, and that fact was visible in the volume of the unit, as we can read on the following dialogue:

Student A – We have inculcated that each 10 is worth a ten, but I think that what they are asking is for the representation, taking into account the order of the units. That is, we can understand that each 10 here is worth one here.

Student B – Our representation is this one (Fig. 6). We aren't using the longs!

Student A – Read the task again… Proceed to your representation…

Student C – Where?

Student B – On the first column, only!… We've been exploring…

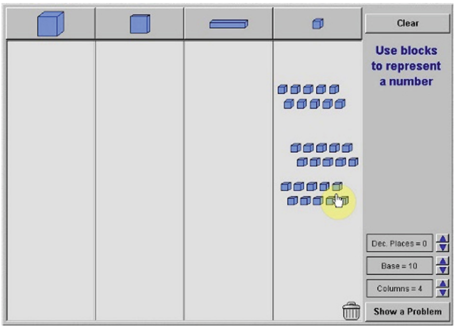

Fig. 6. The group attempts to restart in order to understand how to resolve the task.

They keep debating and trying to register, but the doubts keep appearing:

Student A – Have you noticed that, for example, … This is a long of base 10 (Fig. 7) and the long of base 5… Has…

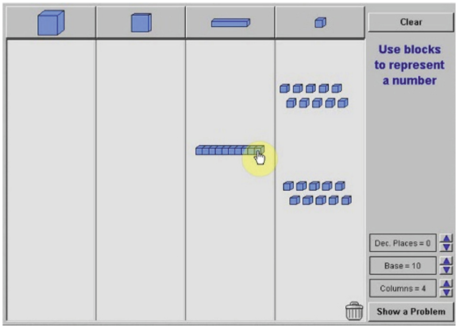

Fig. 7. The group tries to understand the size of the long of base 10.

Student B - … 5 units…

Student A - …Yes, but… It's slightly different (Fig. 8).

Student B – It's larger!… (alleges, without even looking at the long) Ah, it's not larger, (after seeing the long) it's the same, but in base 10 you have 10 units and in base 5, only 5.

Student A – That is, the volume is the same… This part is all the same.

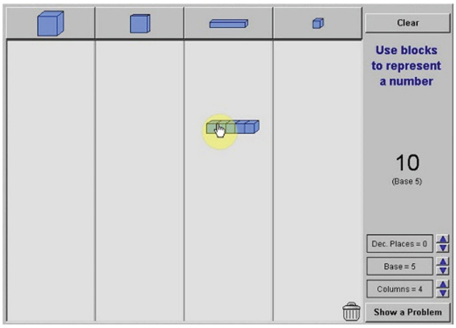

Fig. 8. The group tries to compare the long of base 10 with the long of base 5.

They continue discussing, always showing many doubts about the place value.

Student A – 100 is 10 raised to 2 in base 10.

Student B – Isn't the base behind?… I can't remember… Each group of 2 makes one unit of superior order… - says, interacting with the applet – add 5 and 5… 10 (Fig. 9). The lower the base, less cubes it has.

Student C – But we have larger cubes!… Of a greater volume!…

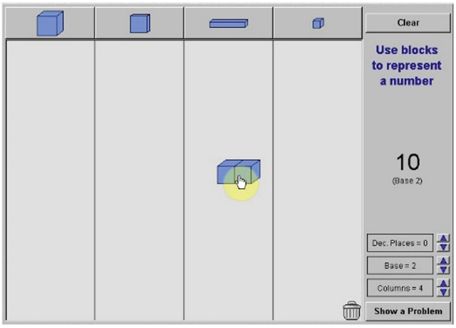

Fig. 9. The group compares the long of base 2 with the other bases.

The group did not understand the place value. The knowledge that the group seemed to present on base 10 vanished when the bases were changed. Here, the group was not able to explain the value of the long or the flat and could not utilize the applet's potentialities.

- Mathematical terminology used

The group does not use the proper mathematical terminology, mainly when the base with which they are working is not the decimal one. In the dialogues, we can understand the existence of statements, such as: "If you already have 2 in base 2, it adds up to a ten."; "If it's in base 5, it means that each 5 units represents a ten". The terminology used in the order's identification was also not the most proper one, even though, when working with a base 10, they referred to the orders of units, tens, hundreds, and thousands, they never referred to the order of the units as the order zero, or the order of the tens as the order one, etc. This apparent ignorance resulted in using the same terms to describe the orders of a base 10 and the orders of a different decimal base. For example, we can read the following on an answer of task 1 b): "Each set of 5 units represents one unit of superior order, which, in this case, is represented by a long, that is, one unit of the order of the tens". They replicate the same idea to a base 2: "Each set of 2 units constitutes one superior order's unit, which, in this case, is represented by a long, that is, one unit of the tens' order." These facts reveal that the FPNS understand was not the best one. It is noted, however, that throughout the two sessions there was an evolution in the concern of using a more precise language. In the dialogues there were language corrections between the group's elements, questioning, even, if they were using the most appropriate terms ("Saying that it is to the rightmost possible, is probably not the most correct way"). The teacher's informal intervention in the group's dialogues was also decisive in the student's use of the characteristic expression of one of the principles of a decimal numeral system: "each set of 10 represents one unit of a superior order". Another factor that contributed to a more thoughtful terminology was the group's discussions. In fact, when they presented their work to the class, it was mandatory for them to express themselves correctly. When they failed to do so, the teachers corrected them. Consequently, the concern in using a more appropriate terminology increased during the second session.

5 Conclusions

The group had an above average perception about their mathematical knowledge. When confronted with the reality, it was verified that they presented frailties in the FPNS, mainly in the principle of the place value. The used terminology was also no the most adequate one.

In response to the investigation's question, the interaction work with the applet allowed the students to visualize, in a more dynamic way, one of the FPNS: the organizing of the elements in a certain order on an equal value of the base and, consequently, the formation of a superior order unit. This fact is in line with the studies of [19]. The classroom's practical model also contributed to an improvement in the understanding. There was many idea exchanges and arguments between the elements of the group, which allowed them to raise conjectures, reflect and reach some conclusions. In fact, it has also been noted that, after a while, there was a bigger concern with the terminology used, with some students correcting others. However, regarding the place value understand, the group interacted very little with the applet. It presented a lot of doubts and arguments between the students took too much time, even more that the foreseen, leading to a lack of conclusions and unaccomplished tasks. Regarding this fact, the group was not capable of taking advantage of the tool they had. It was verified that working with a base different from the decimal presented a big obstacle, concluding that the FPNS were not properly understood.

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Guidance Degree of the Task in the Exploration of a Computational Simulation

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Abstract. The aim of the study was to investigate the influence/efficacy of different kinds of task guidance, in the learning of the changes of the physical state of matter at a microscopic level, with the exploration of computational simulations by 5th-grade pupils. The study has two research questions: (1) "How different task guidance degrees given to pupils, as support to simulation exploration, influence the learning process?" (2) "What evaluation does the student ascribe to the autonomy granted by the teacher?". The study was carried out with four groups. Three guidance degrees of the task was applied by using different worksheets.

Data about the teaching and learning process was collected making use, particularly, of a pre-test and post-test. From the analysis of results, we conclude that learning occurred with all the three guidance degrees. However, the guidance degree of the task influenced learning and conceptual comprehension. The group submitted to a minimal guidance degree obtained lower results than the groups that had moderate and high guidance, and the groups submitted to moderate guidance degree had the best learning results. There were also small differences in the students' perception of the autonomy provided by the teacher.

Keywords: Computer simulations · Task guidance · Particulate nature of matter · Physical states of matter

1 Introduction

The corpuscular theory of matter, a central theory in chemistry, is important for understanding areas of physics and biology [1]. However, in Portugal and in many European countries it is only addressed in the 8th year of schooling. If students in the 5th year of schooling have the idea that matter is formed by particles of a very small size, they understand better processes such as the alteration of physical states of matter and other phenomena studied in the 6th year of schooling as pulmonary hematosis, digestive absorption, and photosynthesis among others. Some textbooks and multimedia materials already include the representation of molecules in the representations

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of phenomena in the form of images, however, they do not present any explanation on the subject. There is evidence [23] that 6- to 8-year-olds can gain sufficient knowledge of highly abstract, basic science concepts that can serve as a cognitive basis for facilitating further learning and consider introducing these early scientific ideas so that the student can connect them with previous ideas and build a gradual understanding of the concepts [14, 22].

Computational Simulations (CSs) can represent matter at a microscopic level. As they are interactive tools, they have been proven to be an important resource for the understanding of a theory as the Corpuscular Theory of Matter because they allow diminishing abstraction, making visible the invisible and the produce of a human construction [4]. In addition, CSs help the student to construct knowledge per se: it is a form of active learning in which the teacher occupies an intermediate place between the information and the students, pointing out ways and reviving creativity, autonomy and critical thinking [21].

The guidance degree that is necessary to provide the student when he/she explores a computational simulation could be a matter of debate. This study intends to evaluate the effectiveness of three task guidance degrees in the use of a computational simulation of PhET, states-of-matter-basics, in learning the changes in the physical state of matter at microscopic level with of the 5th year students (ages 9 to 11).

2 Research Theoretical Framework

CSs used in teaching generally represent a model of a phenomenon/system with which the student interacts and may involve representations of abstract or physical objects. In this context, students construct their own knowledge by conducting experiments and observing the effects of these experiences [24]. The epistemic mediators, including CSs, allow us to work and construct conceptual fields or to build a deeper and deeper understanding of what surrounds us [16]. In a learning environment with CS the representations of abstract objects are used to transform theoretical/conceptual constructions into perceptible representations and with which the student can interact and experiment [24]. The representations of abstract objects provide a more comprehensible view of the concepts and mechanisms underlying a phenomenon [12]. However, there is much controversy about the degree of guidance that must be provided to the student during the learning of scientific concepts, supported by CSs. This controversy is strongly related to the perspectives and approaches to learning. Some researchers consider that students have better learning when they are given little guidance [7], while others argue that a more targeted teaching of concepts and procedures can increase learning. Thus, the high task guidance degree would free the student from the high demands of working memory [13, 18]. Some researchers have concluded that when students manipulate many variables, more targeted teaching seems to be more effective [5, 10, 17, 19]. Gonzalez et al. [9] also consider that some orientation should be given to students and simultaneously the freedom and structure to work with the simulations. When students actively interact with the simulation, the learning outcomes are superior, especially if the student is self-questioning and the questions s/he poses, guide him/her in the exploration of the simulation. Akaygun and Jones [3] studied the effects of different orientation levels on the exploration of a gas-liquid simulation. They observed that although there were no differences in conceptual understanding among groups that used written activities with different guidance degree, comments about both simulation and worksheets on the evaluation questionnaire were more positive for students who had used the open-ended version. Students who had used the open-ended worksheet were also more likely to focus on the content of the lesson in their remarks, while students who used the more guided worksheets were more likely to focus on the structure of the lesson. Chamberlain et al. [8] studied students' involvement with an interactive simulation on acid-base balance and used three written activities with different orientation levels, one with high orientation, one with moderate orientation and one with low orientation, and reported that highly targeted activities can significantly decrease student interaction in the exploration of a simulation by limiting students to using only the resources mentioned in the instructions. The guidance degree must be tailored to the student's knowledge and experience [11]. Providing feedback to students worked examples or explanations during survey learning benefits students and improves learning outcomes [2].

3 Research Problem and Objectives

Usually, students like to work with simulations and get involved in their exploration. Increasingly, suitable simulations are performed at different age levels and in several areas of knowledge with orientations tailored to the needs of the students, and that attend to the cognitive theory of multimedia learning of Mayer [15]. However, there are still simulations with great pedagogical value but with fewer orientations to the student. In these cases, the teacher must create ways to overcome this gap. The purpose of this study is to evaluate the effectiveness of different task guidance degrees in the use of a computer simulation by students and to find what evaluation the student ascribes to the autonomy granted by the teacher. Thus, to answer the research questions: "How different task guidance degrees given to pupils, as support to simulation exploration, influence the learning process?" and "What evaluation does the student ascribe to the autonomy granted by the teacher?", the effectiveness of three task guidance degrees was researched through pre and post-tests and the students' perception about the classroom environment and autonomy provided by the teacher was evaluated by a questionnaire adapted from the Learning Climate Questionnaire of Williams and Deci [26].

4 Methodology

The study was carried out in a basic school in the north of Portugal, in the year 2017. Sixty students from the 5th grade were involved: 33 males and 27 females, divided into four groups. Students were between the ages of 9 and 12. The average age of the students was 9.9 years. Three groups (T1, T2, T3) of the 5th grade were divided (convenient sampling) into four groups, each group with fifteen students. Groups A, B and D consisted of 8 girls and 7 boys, and group C consisted of 9 girls and 6 boys.

In the study, the "states-of-matter-basics" simulation of PhET of the University of Colorado (translated version for Portuguese) was used. The simulation was used to introduce and to explore the corpuscular nature of matter, to review its physical states and the changes of state with variations of temperature.

A quasi-experimental methodology was used in which an equal pre-test and post-test with two parts were applied to all groups. There was no control group. The first part of the test was adapted from the literature [25]. The test has 36 multiple-choice questions with three response options, "increases", "decreases" and "does not change". The issues are related to changes occurring at microscopic level during phase changes, during heating and cooling or application of pressure to solids, liquids and gases. The second part of the test has two questions, one descriptive and one explanatory. In the first question, students were asked to describe the appearance of water in the three physical states of matter to a microscopic dimension. It was also pointed out that for this purpose they could use words, drawings or schemes. In the second question, they were asked to explain the descriptions they had made. The students had 45 min to complete the test. The first test was administered five months before the teaching situations, and the last two weeks after teaching ended.

Three worksheets/activities were distributed to each student to carry out during the simulations, with questions that provided different task guidance degrees. Students worked in groups of two. The first part of the worksheets/activities was common and presented the student with the phenomenon to be investigated, the computer simulation, the variables that she could manipulate and the work question. Worksheet 1 only had this first part (Minimal guidance degree). Worksheet 2 (Moderate guidance degree) also provided a framework for the student to describe the differences and similarities between water and oxygen in the three physical states. There were also three schemes for the student to complete, where variables were related during heating, cooling and during compression (Fig. 1).

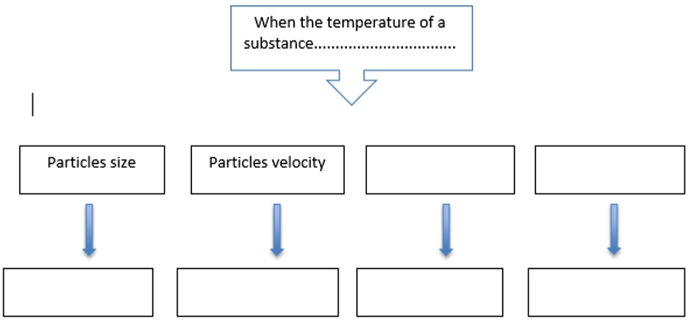

Fig. 1. Scheme to relate variables.

Worksheet 3 (High guidance degree), in addition to the first part, common to the two previous worksheets, had tables for students to record the observations they made after changing the variables (Fig. 2).

Material	When the temperature of... increases, the ...			
	Particles velocity	Distance between particles	Particles size	Particles number
water				
argon				
neon				
oxygen				

Fig. 2. Table of recording of observations and relationship between variables.

Worksheet 2 was distributed to two groups with the purpose of verifying whether there were differences in teaching orientation between the two groups. Group A used worksheet 1 (Minimal guidance degree) and was given full autonomy since the students were free to explore the simulation without constraints of the script. Autonomy was given for the student to be guided in the exploration of the simulation, to make the observations, to collect, to register and organize the necessary data, to allow him to answer the work question and to reach a conclusion. As to the remaining groups, autonomy was conditioned since the students were free to explore the simulation but with constraints imparted by the structuring provided by the worksheets, in the collection and registration of data. However, in groups B and C (worksheet 2 - Moderate guidance degree), autonomy was less conditioned than in group D (worksheet 3 - High guidance degree). At the end of the simulation exploration, students were asked to answer a confidential questionnaire, the Perceived Autonomy Support: The Learning Climate Questionnaire (LCQ) [26], in order to evaluate the classroom environment and the student's perception of the autonomy granted by the teacher in the simulation exploration. This questionnaire consists of 6 items, which competes for a single factor that evaluates the perception of the autonomy support given by the teacher. The answer is given on a Likert scale of 1–7, corresponding to the option "Totally Disagree" (value 1) and "Totally Agree" (value 7). The score was calculated by averaging the scores of the individual items.

After the simulation exploration, there was a discussion class in each group. The classes were recorded, and the images were taken during the simulation exploration.

The multiple-choice questions of the first part of the pre-test and post-test were grouped in two ways: according to the type of variable mentioned (speed, distance, size and number), during phase change of matter, transfer heat or compression; according to the phenomena of change of variables without occurrence of change of physical state, change of physical state and compression.

The descriptions and justifications carried out by the students in the second part of the pre-test and post-test were analyzed, and from this, the definition of 6 response profiles resulted (Table 1).

So, when the student represents water in the solid state as an ice cube or when drawing water flowing from a faucet or a river, it is describing the visual perception of water. This response profile was codified as profile 1. The answer "Ice is in the solid state" is an example of this profile. When the student describes the physical states of

Table 1. Profiles and response profiles respectively

Profile	Response profiles
0	Wrong answer and/or alternative conceptions
1	Identifies the states of matter associated with sensory perceptions (visual, tactile aspect)
2	Identifies matter as being formed of particles but with the same properties of matter in the macroscopic dimension
3	Identifies the states of matter associated to phase change and may or may not be associated with sensory perceptions
4	Identifies particles in the three states but only lists one of the variables (velocity, size, space, and distance)
5	Identifies particles in the three states and relates at least two variables to each other (velocity, size, space, and distance)

matter, either by drawing or by a short answer, referring to the phase change ("I melted, and I am in the liquid state, like the waters of the seas"), profile 2 is codified. In profile 3 the student already refers to the existence of particles and assigns them the same properties as a sample of matter with a macroscopic dimension ("solid state-particles together: frozen; gaseous state: heated particles").

The student with profile 4 already says that water is formed by particles and describes the phase in which water is found by relating it to a variable ("water in the liquid state, the particles are closer because their temperature is low"). The student with profile 5 identifies particles in the three physical states of matter and relates the different states to at least two variables ("When it is in the solid state the particles stay together and the velocity decreases when it is in the gaseous state, the size does not change and the speed increases").

5 Results

Comparing the overall results of the first part of the pre-test with those of the post-test in each group, we can observe that that Group B had the highest gain of correct answers, followed by Group C. Groups D and A had very close gains but smaller than the two previous groups (Fig. 3).

It was also found that there is no statistical evidence to assert that the groups before the teaching situations are significantly different in the first part of the pretest (Kruskal-Wallis H3 = 6.605, p-value = 0.086 for $\alpha = 0.05$) and in the second part of the pre-test (Kruskal-Wallis H3 = 6.653, p-value = 0.084 for $\alpha = 0.05$).

From the analysis by group and type of question (Table 2), we can observe that group B obtained greater relative gain in the questions "particle size", "particle velocity" and "particle number", followed by group C. Group C obtained a greater relative gain in the questions "space between particles". Groups A and D obtained lower relative gains in all groups of questions.

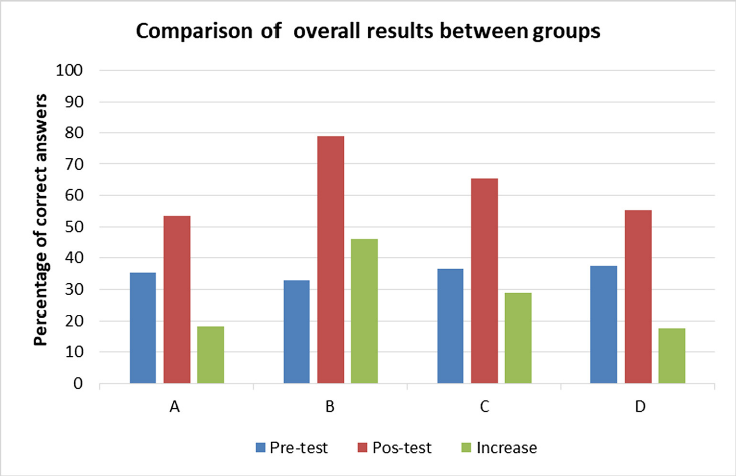

Fig. 3. Comparison of the results of the 1-part of the pre and post-test.

Table 2. Pre-test results (%) and relative gains by groups of questions and by group of students

Group	Group of questions							
	Particle size		Space between particles		Particle number		Particle velocity	
	Pre-test	Relative gain	Pre-test	Relative gain	Pre-test	Relative gain	Pre-test	Relative gain
A	24	0.30	43	0.19	34	0.38	34	0.30
B	15	0.73	51	0.32	32	0.80	29	0.64
C	18	0.64	48	0.39	37	0.52	41	0.38
D	17	0.28	48	0.23	33	0.43	45	0.27

The relative gains in "particle space" issues are, in all groups, lower than in the other issues. These results may be related to the fact that in the simulation, water, a substance with a behavior that is different from other materials in the solid and liquid state, led to different responses by students.

Concerning the questions about "change of variables without change of physical state", "change of variables in change of physical state" and "change of variables in compression", the relative gains of groups B and C remain higher than those of groups A and D. However, group D stands out from group A on compression issues and presents relatively close gains as compared with group C (Fig. 4).

After the teaching situations, there is statistical evidence that in the first part of the post-test groups B and C are not significantly different (Mann-Whitney Test U = 73.5 *p* value = 0.105 for $\alpha = 0.05$) and that Group B is significantly different from group A (Mann-Whitney Test U = 38,000 *p* value = 0.002 for $\alpha = 0.05$) and group D (Mann-Whitney Test U = 34,500 *p* value = 0.001 for $\alpha = 0.05$).

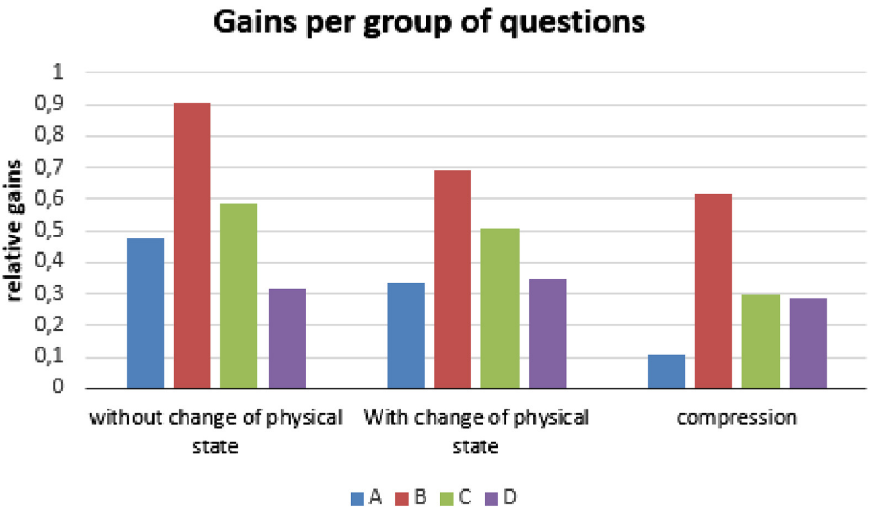

Fig. 4. Relative gains by groups of questions and by group

Regarding the analysis of the second part of the pre-test and post-test, we find that groups A and C focus (median) on Profile 1 in the pre-test and groups B and D focus on Profile 2. In the post-test, it is verified that group A focuses on Profile 2, Group C on Profile 3 and groups B and D on Profile 4. Comparing the 75-percentile of the groups, it is verified that in Group A P75 is 2 and in groups B, C and D P75 is 4 (Table 3).

Table 3. Descriptive statistics

Descriptive statistics								
Group	A		B		C		D	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
$\ddot{X}$	1	2	2	4	1	2	2	4
Medium	1	2	2	4	1	3	2	4
P75	2	2	3	4	1	4	3	4

By analyzing the profile of the students, 7 (47%) of Group A remained in the initial profile, against 4 students (27%) in Group B, 3 (20%) in Group C and 5 (33%) in Group D. In Groups A, B and C, 5 students (33%) and in Group D, 4 students (27%) passed to the immediate following profile (Fig. 5). It is also verified that in Group C 5 students (33%) went up two profiles, 1 student (6%) went up 3 and another one 4 profiles (Fig. 5).

Observing the ordered profile of the students in the pre-test and the post-test, we can observe that the groups with the best performance were B and D, followed by group C. Group A had the worst results (Fig. 6).

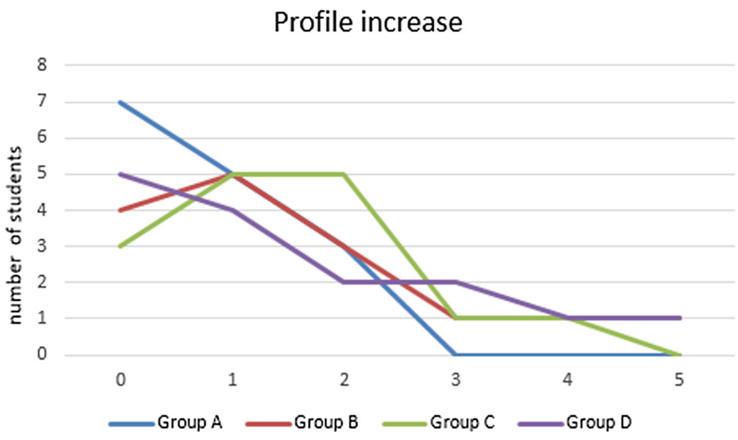

Fig. 5. Increase in student profile

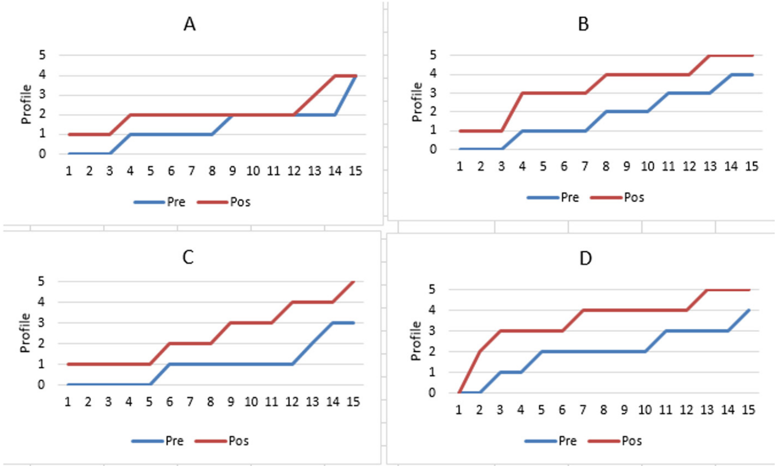

Fig. 6. Ordered student profile

Making an overall assessment of the results of the 1st part of the test (multiple choice) and the 2nd, one observes that the group with the worst results was group A and, therefore, the type of task orientation (minimum) used was not as effective as the others. Group D, despite having a lower score in the 1st part of the test (multiple choice) performed better in the 2nd (descriptive). These results suggest that in the study of physical states of matter at the microscopic level with CS exploration, providing students with moderate orientation or greater task orientation has superior learning effects than a minimally oriented task. Regarding the results of the "classroom environment" questionnaires, Groups A and B are centered on the value 6 and the other two groups are close to the value 6 (*I agree*). According to this value, the students felt that they were given autonomy in the exploration of the simulation. However, groups C and D felt that they were given less autonomy than groups A and B (Table 4).

Table 4. Classroom environment

Group	Average scores for individual items			
	A	B	C	D
Average scores	6.1	6.2	5.9	5.6

6 Conclusions

The objective of the present research was to evaluate the influence/efficacy of different task guidance degrees in the learning of the changes in the physical state of matter at microscopic level, with the exploration of CS by 5th-grade students. In order to do this, we compared the learning of 4 groups of students with an interactive simulation using three levels of task orientation, through work-sheets provided to the students to support the exploration of the computer simulation and evaluated the perception that the students had about the classroom environment and autonomy provided by the teacher.

We observed that the design of the activity, in terms of guidance degree, can influence student learning. The results suggest that the guidance degree provided by worksheets that the students used to support the use of computer simulation had different effects on their learning. Thus, the group submitted to a minimal guidance degree had lower results than the groups that had a moderate guidance degree, and the group that had a high guidance degree and the groups submitted to moderate guidance degree had the best learning results. These results are in agreement with those obtained by Moli et al. [20] and by Araújo et al. [4] and, according to the idea of Bjork et al. [6], who consider it necessary to provide difficulties to the student (desirable difficulties) in order to enable the initiation of coding and retrieval processes that support learning. This study shows that different levels of implicit task guidance through written activities may lead to different outcomes in student learning.

It was also found that the students felt that they were given autonomy in the exploration of the simulation and that there were no significant differences in the quality of autonomy that was provided. Thus, it is concluded that in CS exploration, it is necessary to provide sufficient guidance to the students, so that learning and conceptual changes do occur, and some kind of moderate guidance has potential that can be better researched.

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An Approach to Sound and Acoustics in Primary Education Using Arduino

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Abstract. In recent years the rapid pace of digital advances made technological devices more accessible to a wider public and broaden their application scopes. Nowadays, schools have easier access to several technological resources, striving teachers to turn teaching and learning processes more fun, dynamic, engaging and effective.

In this study we evaluated the use of two technological resources, Arduino boards and smartphones, as science teaching tools for primary education. In this case study, we focused on a sample of 1st cycle of Basic Education students, averaging an age of 9 years old. We followed a methodological design that combined technologies with experimental work to explore natural sciences curricula, thus promoting the development of epistemic practices and the development of skills for the digital age in which we live.

Keywords: Technology · Experimental science teaching · Arduino · Smartphones · Epistemic practices

1 Introduction

Children are motivated to learn in multimodal manner, have a natural intuition to use technology and like fiddling in digital devices since early ages. Therefore, technology has an immense potential to leverage new educational tools and to encourage collaboration. The creation of learning environments by embracing and incorporating technology within classroom is widely recognized as a current need.

This need has also been identified in the Portuguese educational system and was legally enforced by the Portuguese Council of Ministers Resolution 137/2007, which states that it is essential to enhance and modernize schools, to create the physical conditions that favor students' educational attainment and to consolidate the role of information and communication technologies (ICT) as a basic tool for learning and teaching in this new era. The main objectives identified are content development and open source software promotion. The proposed strategies involve the promotion of

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scientific literacy, enhancing the attractiveness of teaching and learning processes and using real life connections in classroom.

There are several constraints usually identified by teachers in the use of technology, which do not allow to take full advantage of technology as a pedagogical tool. These include insufficient technical support, lack of resources and low financial investment [1]. The use of low-cost, versatile and daily use tools, accessible for students and teachers, seems to be the most obvious and efficient solution to tackle these problems. Two technological artifacts that precisely meet these requirements are the smartphone and the Arduino board. Smartphones are devices that students use on daily basis, and it allows them to register and collect multisensory data [4]. The Arduino board is a low-cost tool, based on an open-source software, easy to use and that allows everyone to build its own smart devices, that interact with the environment [10].

The Arduino platform was launched in Italy in 2005, aiming to support small automation projects, especially for people with low programming skills [9, 10]. The board consists of a circuit with inputs and outputs (6 analog inputs and 14 digital inputs/outputs), which allow the use of LEDs, LCDs, motors, buzzers, among other digital dispositive [10, 11].

The board can be powered via USB or external power supply. Voltage input should vary between 7 V and 12 V.

The board's constituent microcontroller, ATmega328, can be programmed using a specific software developed by the Arduino community. The programming language available to the user is based on C/C ++ [2, 7].

The Arduino platform can be integrated with several sensors, thus allowing to custom build digital devices that can provide fast registration, processing and data visualization of several environmental, physical or chemical variables. This is an additional advantage to all previous ones mentioned, since these devices let students analyze and interpret results in more precise and exact ways [7].

Smartphones can be enablers of learning processes and can be considered as smart pedagogical tools, due to their services and content [8]. Given that millions of people use smartphones on their daily life, they can be considered an ubiquitous tool, that both students and teachers should be able to use efficiently and with little effort [8]. The use of these devices does not represent extra expenses for the school and allows the exploration of several integrated sensors, such as the accelerometer or luminosity sensor [4].

When students observe, formulate hypotheses, and perform other tasks related to scientific activity - epistemic practices - they are building capacities to deal with scientific knowledge. If students are led to develop epistemic practices, they can mobilize prior knowledge, build a better conceptual understanding and develop high-level skills [3].

In this work, we investigated the use of Arduino and Smartphones as pedagogical tools through their integration in an experimental design to assess the acoustic conditions of the school. The main tool of this study is the Arduino board, due to its potentialities, but also to the lack of information about its utility in teaching. As a validation method, we also tested the use of a smartphone application that emulates a sound meter, using the built-in microphone to measure the levels of ambient noise (in decibels).

In this research, we evaluate the usefulness of Arduino to develop scientific knowledge and scientific attitudes, i.e. to promote epistemic practices. More specifically, we meant to understand how Arduino contribute to the development of skills related to acoustics and also how it helps to develop scientific attitudes in students, fostering epistemic practices. Thus, he main objectives are: (a) to investigate the potentialities of Arduino to implement experimental work in natural science classes, (b) to validate an assemblage and programming protocol of an Arduino sound sensor, to be used in experimental context in primary education; (c) to promote active learning of acoustic concepts using the Arduino platform.

2 Research Methods

This study involved a group of students from 1st cycle of Basic Education, in a school located in the district of Porto, Portugal. The class had 21 students, 9 boys and 12 girls.

In this work a mixed character methodology was used, using instruments that provide quantitative and qualitative analysis. This methodology offers the teacher-researcher a broader view of the results, allowing more effective comparisons. Also, this approach allows personal reflections about his own practice, in order to improve its mediations [5].

The methodology was based on participant observation and direct observation grids with different levels of skills assessment, photographic and audio recordings, student productions throughout the sessions and the analysis of two surveys answered by the class, a survey applied before the sessions were held (pre-test) and another applied at the end of the sessions (post-test). The categories of analysis were initially defined according to the established objectives (Table 1).

Table 1. Categories of analyses

	Categories of analyses
1	Significant learning related to acoustics
2	Viability of mounting and programming a sound sensor using the Arduino board
3	Promotion of epistemic practices

The activities that were carried out during this research were previously planned taking into account the students' group, its year of schooling and all the previously studied contents. These activities were implemented in four sessions of ninety minutes each. A summary scheme of the activities performed in the sessions can be seen in Table 2.

The first session was dedicated to the study of sound characteristics, since this was still unfamiliar content to students, and about which they had some doubts. As a way of approaching these contents and making learning more meaningful, we used some didactic resources such as "air cannon" and an auditory test in which the sound frequency is varied. It was also explored an Arduino board, as well as its practical

Table 2. Activities held in each session

Session	Example
1	Implementation of the pre-test Initial approach to the study of sound Introduction of the Arduino board (operation and utilities)
2	Assembly of the devices Device programming Testing and minor adjustments to the program
3 and 4	Measurement of sound intensity in different places of the school Presentation of results Reflection and comparison with reference values Implementation of the post-test

applications. In this session were also explored the predictions of the students of the places and times where the sound intensity was higher, leading to a certain discomfort.

The second session, dedicated to the assembly of the devices, was initiated with a presentation of the materials to be used and some indications to the way some of them had to be connected. Although, during the assembly process, all groups were monitored, students were given total freedom to analyze the assembly scheme.

After assembling and verification of the devices the programming followed, which began with an introduction to the software and the main commands. The code used was previously structured, being only necessary, after defining the pins according to the connections made on the board, to indicate for which values a specific LED is present.

The sound intensity values measured with the *KY-038* sensor were monitored in real time through the Arduino "monitor" serial function and with the smartphone "decibel meter". Based on these values, sound comfort intervals were defined [comfortable - the green LED lights up; little comfortable - lights the yellow LED; uncomfortable - lights the red LED]. It should be noted that each group had the responsibility to study the sound intensity in different places of the school and that each sensor was programmed according to them. Thus, the defined sound comfort intervals were different according to the location.

After defining these values, performing multiple tests and code changes resulting therefrom, the measurement of the sound intensity in the various places of the school was followed. To make the devices portable it was decided to change the power supply of the board that until then was the computer, to using a 9 V battery. With the smartphone it was intended to measure the sound intensity (in decibels) and then make a comparative analysis with the reference values indicated by the World Health Organization (WHO) previously provided to the students.

It should be noted that in each place two measurements were taken, one during the classes and another between classes, since during the first session the group concluded that the sound intensity in the different places varies according to the school schedule. In this way, it would be possible to study when the sound intensity was higher and conclude about the causes for this evidence. After collecting and recording the data, the results of the comparative analysis with the reference values and a reflection on the conclusions to be drawn were followed in a large group. The final task of these sessions was the post-test fulfillment.

3 Results and Discussion

First of all, it should be mentioned that some students were not present in all sessions. Therefore, the number of initial students (n = 21) differs from the number of students present in all sessions of the project (n = 18). This fact must be considered when interpreting the obtained results. It should also be noted that the figures presented are merely indicative of the evolution of the students during the sessions, and it is not possible to verify that the students who indicated that they did not reach a certain competence did not actually reach it.

Regarding the first category of analysis related to the development of significant learning regarding acoustics, it was possible to draw some considerations between the previous knowledge about this question and the knowledge after the implementation of the project. Thus, by analyzing the table of results for sound and acoustic knowledge evaluation (Tables 3 and 4), it is possible to verify a considerable evolution.

Table 3. Direct observation grid - acoustics

Evaluation of acoustic knowledge	Sound intensity	Noise-consequences relation	Usefulness of sound study	Sound measurement	Data interpretation
Level 0	Doesn't understand the meaning and don't use the correct nomenclature	Doesn't identify the consequences of high sound intensity	Doesn't understand the usefulness of measuring sound intensity	Doesn't correctly use the sound intensity measurement tools	Doesn't interpret data correctly
Level 1	Understands the meaning but doesn't use the correct nomenclature	Identifies the consequences of high sound intensity	Understands the usefulness of measuring sound intensity but cannot justify	Correctly uses one of the sound intensity measurement tools	Correctly interprets the data
Level 2	Understands the meaning and uses the correct nomenclature	–	Understands the usefulness of measuring sound intensity and can justify it	Correctly uses all sound intensity measurement tools	–

Table 4. Analysis of the number of students who achieve each criterion for assessing knowledge relates to acoustics before and after the sessions

Evaluation of acoustic knowledge		Sound intensity	Noise-consequences relation	Usefulness of sound study	Sound measurement	Data interpretation
Level 0	Before	2	4	11	–	–
	After	0	0	0	0	0
Level 1	Before	18	17	7	–	–
	After	11	18	4	0	18
Level 2	Before	1	–	3	–	–
	After	7	–	14	18	–

It is possible to verify (from Table 4) that in the understanding of the consequences that the exposure to a high sound intensity can imply there was a significant evolution, since all the students who participated in the four sessions were able to reach the maximum level predicted for this parameter. The evolution referring to the understanding and use of the correct nomenclature related to the sound intensity and to the parameter referring to the understanding of the usefulness of the sound study was less significant. In relation to the first one, it was possible to verify that all the students who participated in the 4 sessions understood the meaning, but that even more than half of them did not use the most appropriate scientific nomenclature. As for the second one, although all the students who participated in the 4 sessions evidenced to understand the importance of the study of the sound, and of more than half could justify this same importance, about 2 students were not able to do it. This evidence is also substantiated by the analysis of the question "Do you think it is important to measure the sound intensity in schools?" answered by the students in both surveys (Fig. 1).

Regarding the parameters related to the measurement of sound intensity and interpretation of results, all students reached the maximum level predicted. It is also possible to verify the comprehension of the importance of the measurement of the sound after the sessions by the students' answers to the question "If you had the opportunity to use a sound sensor outside the school where you use it?" of the post-test (Fig. 2).

Here it is possible to verify by the options taken and by the justifications that more than half of the students who answered the post-test were able to mobilize knowledge, to understand the importance of measuring the intensity of the sound and to apply it to different situations. Another evidence of the importance of studying sound intensity was that, at the end of the sessions, the class showed interest in disseminating the results obtained to the remaining classes and to seek solutions for the cases that were more worrisome, such as the school break. It was also possible to verify that 20 of the 21 students who answered the pre-test indicated knowing at least one law on sound. Of the laws referred to only one was concerning out-of-school noise, 2 students did not indicate any law and the remaining 17 indicated laws related to classroom and library rules.

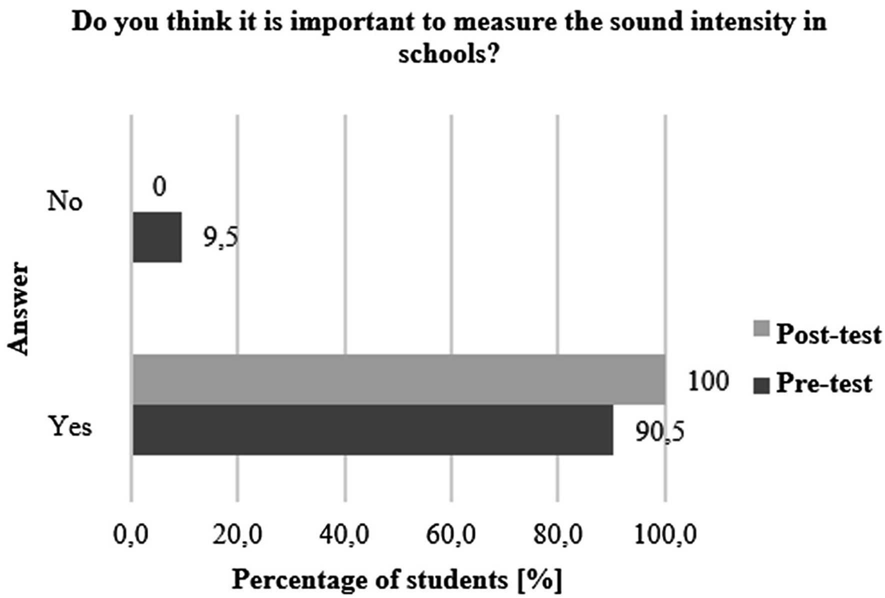

Fig. 1. Comparative analysis of students' responses to the question "do you think it is important to measure the sound intensity in schools?" in both surveys.

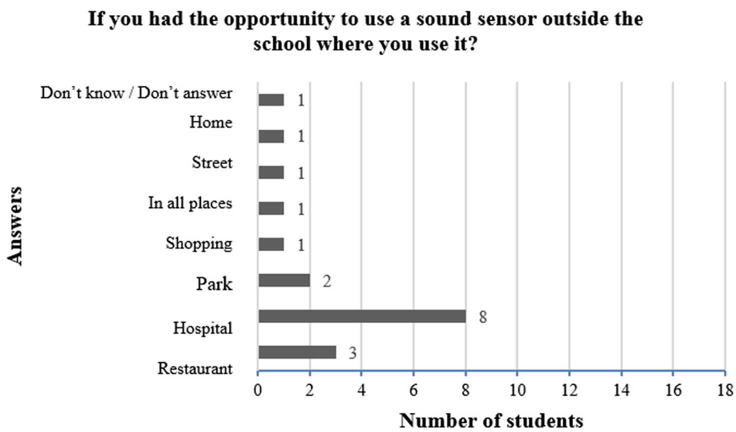

Fig. 2. Analysis of students' responses to the question "if you had to use a sound sensor outside the school where you use it?"

As for the second category of analysis, on the feasibility of sound sensor assembly and programming, it is possible to infer from the analysis of the table of results (Tables 5 and 6), regarding the evaluation of the competences evidenced in the assembly and programming of the sound sensor, the feasibility of these activities in this age group, evidencing again that the maximum freedom was granted to the students.

Table 5. Direct observation grid – competencies evidenced in the practical work

Evaluation of the competencies evidenced in assembling and programming the sensor	Assembly of the sensor	Programming of the sensor	General understanding of work
Level 0	Doesn't participate and doesn't reveal autonomy in the assembly and resolution of problems related to it	Doesn't participate and does't reveal mobilization of knowledge and skills related to programming and acoustics	Doesn't participate in the work dynamics and does't understand the experimental activity
Level 1	Participates little and reveals little autonomy in the assembly and resolution of problems related to it	It participates little and reveals little mobilization of knowledge and skills related to programming and acoustics	Participates little in the work dynamics and understands little the experimental activity
Level 2	Participates and reveals autonomy in the assembly and resolution of problems related to it	Participates and reveals mobilization of knowledge and skills related to programming and acoustics	Actively participates in the work dynamics and reveals understanding about the experimental activity

Table 6. Analysis of the number of students who achieve each competency evaluation criteria in the practical work

Evaluation of the competencies evidenced in assembling and programming the sensor	Assembly of the sensor	Programming of the sensor	General understanding of work
Level 0	0	0	0
Level 1	3	0	0
Level 2	18	21	21

It is important to consider the analysis of the students' answers in the pre-test to a question regarding the use of sensors, which allows to verify the low familiarity of the students with the use of sensors. Only 6 of the students said they had already used sensors and of these only 2 have used a sound sensor. It is relevant to indicate that the students who indicated the use of the sound sensors referred to a study carried out in the school in the previous school year and that had as objective the measurement of the intensity of the sound in the canteen. Despite being aware of this activity, the class was not aware of the results and did not have the opportunity to work directly with the tools used, having only a passive role in this process. Thus, it can be considered that there was no effective work of the students with sensors in the school. As for the utility of the sensors in the study of sound, only 9 students recognized it. This could be related to the lack of familiarity with the use of sensors, since, as previously mentioned, after working with them, the students were able to recognize its usefulness and transpose it to different situations and locations. As for the effective work in the assembly (Fig. 3) and programming of the sound sensor, it was possible to verify that all the students who participated in these tasks reached the maximum level predicted for the parameters regarding the programming of the sensor and the general understanding of the work done. Regarding the parameter related to the assembly of the sensor, all students were at the maximum level, except for 3 that were not very participative in the activity. When questioned about this attitude it was possible to understand that these students were afraid to manipulate the materials and to make some mistake. This attitude has been changing throughout the activity evidencing an increasing involvement and autonomy by these students, encouraged by the group's colleagues, by the teacher and by the nature of the work accomplished.

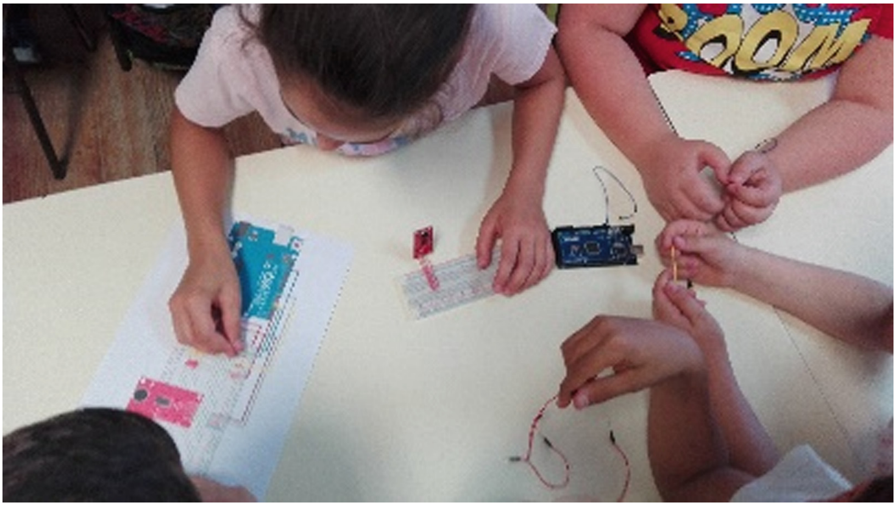

Fig. 3. Devices assembly process.

Another way to verify if the assembly of the sensor was significant for the students was the analysis of the drawing they performed in the post-test (Fig. 4). It should be noted that this drawing was performed without the students observing the devices. In the analysis to these drawings it was possible to verify that all the students elaborated illustrations visually next to the sensor of sound, with different degrees of detail. It should be noted that all components, apart from resistances (which was represented by only 7 students), were represented by more than half of the students who answered to the post-test.

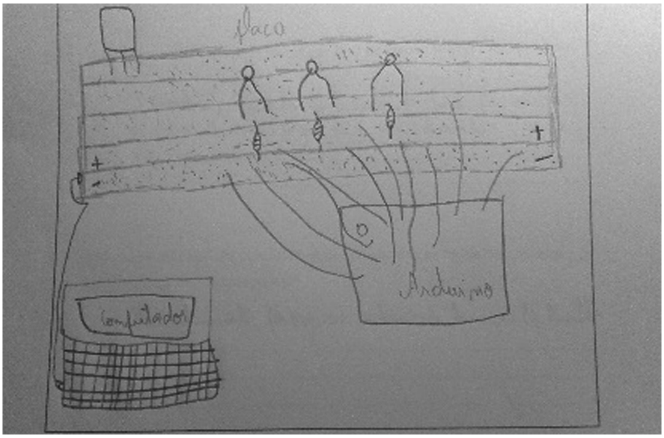

Fig. 4. Example of a drawing of the assembly scheme drawn up by a student.

Table 7. Checklist of the occurrence of epistemic practices throughout all sessions

Epistemic practices[a]	1st session	2nd session	3rd session	4th session
Description of physical phenomena or events		X	X	X
Formulation of issues, problems and hypotheses	X	X	X	X
Manipulation of technological objects dexterously		X	X	X
Identification of CTS components in a problem	X	X	X	X
Relationship of physics with everyday phenomena	X	X	X	X
Collection, treatment and organization of relevant information			X	X
Problem-solving		X		
Evaluation of the solution and resolution			X	X
Experiment planning	X	X		
Obtaining and processing data during the search for results			X	X
Measurement of physical quantities		X	X	X
Calculating capabilities			X	X
Establishment and use of relationships (functional or causal)		X	X	X
Explanation of a phenomenon or event	X	X	X	X
Transformation of a language in another		X	X	X
Communication of results and ideas using message-adapted media and tailored to the recipient			X	X

[a]Adapted from reference [3]

It can be inferred that the work with Arduino and the remaining components was indeed significant. As for the last category of analysis considered, the promotion of epistemic practices, it was possible to verify, through the checklist of the occurrence of epistemic practices throughout all sessions (Table 7), that all predicted epistemic practices occurred in at least one of the sessions. It is also possible to verify that the introduction session was the one with the least epistemic practices promoted, 31.3% of the considered ones, and that in the third and fourth sessions, 87.5% of the epistemic practices were promoted to 68.8% in the second class. It may be considered, therefore, that the use of Arduino in the classroom context allows the promotion of epistemic practices in students.

4 Final Considerations

The project was focused on Arduino and its applicability in teaching experimental sciences, associated to the study of the sound and acoustic conditions of the school. Results shown that the use of Arduino is feasible when working with students of this age group, promoting the development of significant learning, and promoting epistemic practices. It also developed some civic awareness, as students understood their influence in increasing the intensity of sound and also raised awareness about the harmful effects that loud sound has on health.

Scientific skills and attitudes have been developed, giving students greater familiarity with scientific concepts, terms and data, thus promoting scientific literacy. It has also been found that by using these technologies, students play an active role in building knowledge, participate in interesting activities and take initiatives for new tasks and research further information about the subject under study. Due to time constraints, it was not possible to conduct more sessions under this study, but it would have been relevant to use these data to raise awareness in the educational community about the importance of sound quality and comfort in schools.

As a conclusion, this study showed that Arduino platform can be effectively used in experimental teaching of natural sciences. In this particular case, it was used for the study of sound properties and noise effects. However, others sensors can be used, at low cost to schools and requiring little effort and skills by students and teachers to assemble and program them. Hence, Arduino has the potential to become a widely used pedagogical resource available in primary schools.

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Computer Algebra Systems and Dynamic Geometry Software as Beneficial Tools in Teaching and Learning Linear Algebra

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Abstract. Teaching linear algebra using technology is a didactic recommendation long known in the literature. This study looked at the implementation of a teaching design by a linear algebra teacher, in particular for actions using computer algebra systems (CASs) and dynamic geometry software (DGS) and for the attitudes and reactions of the students. From the analysis of multimodal narratives (MNs) of some classes, roles were identified that can be attributed to the software used, as well as behaviours that can be revealed by users in linear algebra classes. The collected information made it possible to conclude how these software programs can become beneficial tools in the teaching and learning of linear algebra.

Keywords: Teaching practices · Multimodal narratives · Beneficial tools

1 Introduction

This study deals with the problem, "How can teachers use digital tools in the teaching of sciences and technology (S&T) and in the learning of their students?". It fits in the field of higher mathematical education and, in particular, in the teaching and learning of linear algebra.

Research on the teaching and learning of linear algebra has existed for three decades. It was strongly encouraged by the curriculum reform led in the United States in the early 1990s by the Linear Algebra Curriculum Study Group (LACSG). One of the group's main recommendations was the use of technology in linear algebra classes, mainly computer and mathematical software programs – computer algebra systems (CASs) and dynamic geometry software (DGS) [1].

The relation of linear algebra with technology was considered natural, because: (1) "linear algebra is the mathematics of our modern technological world of complex multivariable systems and computers" [2, p. 3], and (2) it aligns with a belief in the importance of digital environments in supporting the teaching and learning of linear

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algebra "as part of a 'system of means' which include lectures, text, as well as traditional paper-and-pencil problems" [3, p. 372].

In an initial phase, some researchers anticipated possible roles to attribute to the use of the computer and the different software programs in linear algebra classes, namely:

- Their use in the solution of exercises (also outside the class) reinforced the concepts learned, allowed to discover new concepts and to solve realistic applied problems [1];
- Throughout the lesson the technology allowed to explore significant examples, confirm or refute initial intuitions and formulate or test conjectures [4];
- Use of technology in the solution of tasks allowed to surprise (by the results obtained), to clarify theoretical aspects, and to investigate phenomena [3];
- In the particular case of DGS, this software allowed to explore the visual nature of concepts and to observe and deduce properties [5, 6].

Regarding the concepts of linear algebra, the use of CASs has been associated in some investigations with matrix manipulation and the resolution of systems of linear equations (e.g., [7, 8]), although they are also suitable for working with concepts of R^n (e.g., [9]). Many of the more recent textbooks have incorporated sections about these concepts to be solved with the aid of CASs (e.g., [10, 11]). In other works, CASs are considered by researchers to enhance the exploration of various applications of linear algebra (e.g., [12, 13]).

DGSs appear mainly in investigations related to concepts of the theory of vector spaces and with linear transformations, when the vector spaces considered have a dimension no larger than three (e.g., [6, 14, 15]). As advantages, this kind of software allows "contact" with the objects of these more abstract theories [6] and helps students in the construction of mental processes [5]. More surprising is the use of the DGS GeoGebra in exploring the concept of determinant of a square matrix and its calculation [16].

The teaching practices of higher education mathematics teachers are still little investigated [17]. The same is true, in particular, for linear algebra. Considering this fact, this study attempts to connect the practices of linear algebra teaching to the recommendation of the literature for the use of technology. This connexion becomes relevant because any comment made on a (digital) tool can not be dissociated from the user (in this case, the teacher is considered the main agent) and the purpose of use [18].

Looking at the teaching practices of a linear algebra teacher (first author) and considering the functions attributed to the use of software in the literature (and others identified by the present authors), this study intends to answer the following research question: How can the digital tools CAS and DGS be used as beneficial tools in teaching and learning linear algebra?

2 Methodology

2.1 Research Design and Participants

The research method was action research, according to the critical paradigm, with the teacher taking a central position in the development of research. At different times, he acted as a teacher and as a researcher. By its nature, research is qualitative, since the classroom is the direct source of the data, the facts supporting the study results are described extensively and in detail, and the data are analysed in an inductive way.

In the planning phase, an original text of linear algebra was elaborated [19], including, among others, the recommendation of the literature to use technology in the teaching of linear algebra. This text had as its main goal to embody the teaching design outlined and guide the teacher's practice in the teaching of linear algebra. The subjects covered were matrices, systems of linear equations, determinants and vector spaces. Throughout the text, it is proposed to use the chosen CAS – Scilab – to help solve different types of tasks, particularly the verification and illustration of properties and the solution of realistic applied problems. It was also the software used in the presentation of several examples and solved exercises. The illustrations accompanying the geometric interpretation of some concepts were constructed in GeoGebra and Mathematica, in the context of R^2 and R^3, respectively.

The teacher implemented the teaching design guided by the above-mentioned text. This action took place in an electrical engineering course, in the Portuguese public polytechnic institution where the professor taught. Throughout sixteen lessons, each lasting one hour and forty-five minutes, the teacher taught topics as they were presented in the text. Students used it like a textbook. Of the total number of students (thirty-one), eighteen went to class regularly.

Regarding the use of technology, the teacher projected the way he used Scilab, in the exemplification of concepts and in the solution of exercises, and the software GeoGebra and Mathematica in the geometric exploration of some concepts; the students used their laptops and only Scilab. In the institution, there are no licenses for students to use any software that is not free.

2.2 Multimodal Narratives and Analysis

The classroom was the natural setting where most of the data was collected by the teacher: audio recordings of the classes and the students' written productions (daily notebook and tasks solved in groups). The lesson plans and the teacher's notes recorded at the end of each lesson were also considered as instruments of data collection.

These data were constituted as independent data in the construction of the multimodal narratives (MNs) of five classes. Multimodal narratives are an instrument that "gathers, aggregates, organizes and transforms classroom data about teaching practice […] to produce a complete and concise document that may subsequently be analysed, avoiding the difficulty of handing multiple data sources" [20, p. 416]. An MN is a storyline, normally written by the teacher himself, in an exempt manner, describing in detail all the events that took place throughout the class. In addition to including excerpts from the independent data, the MN may include other multimodal elements, such as the teacher's intentions and decisions, and the teacher's and students' attitudes and reactions, gestures, silences, etc. (dependent data) [20].

In the construction of each MN, the teacher (first author) followed the established protocol [20]: after (1) collecting all the data, he (2) listened to the recording of the respective lesson, crossed it with the different data collected and started the construction of a document containing, in different parts, the contextual information, the synthetic narrative of the lesson and the succinct narration of each episode, progressively enriched with the multimodal elements. He then (3) requested peer review (including the second author), the document being finalized and sealed after being accepted as the final version.

The next phase, with the teacher assuming a new role – of researcher – was the content analysis [21] of the MNs. For the study presented here, only one dimension of analysis was considered: the use of the computer and the different software programs by the teacher and the students. With the help of the NVivo qualitative research software, the process started with reading the five MNs and selecting all excerpts related to this dimension of analysis. It followed the "open code" categorization, although attentive to the advanced suggestions in the literature (Sect. 1) in the category creation process (Table 1).

The next section presents the qualitative analysis of the categories identified in Table 1. These categories reveal the practices achieved by the teacher and the work done by the students involving the computer and the different software programs used in the linear algebra classes.

3 Results

The first reading of the MNs aligned with the expectation that it was necessary to look at "for what" and "for what purposes" the different software programs were used. The first sub-dimension – Software function (Table 1) – was thus identified. Some categories of this sub-dimension have emerged from literature. Discovering and clarifying concepts with the help of CAS were functions previously suggested by researchers [1, 3], to which was also associated the DGS to explore, where possible, the visual nature of concepts.

The categories of calculations and the anticipation of some concepts emerged from the data, although it is anticipated that the exploration of more significant examples [4] would naturally imply complex calculations.

It was verified *a posteriori* that there were behaviours of the teacher and of the students associated with the use of the computer and the different software programs. From this observation emerged a second sub-dimension: Attitudes. The emergent categories in the two sub-dimensions focus mainly on the actions of the teacher, although some also focus on the students simultaneously or exclusively.

Table 1. Categories of dimension use of computer and software.

Sub-dimensions	Dimension: use of computer and software	
	Category/code	Description
Software function	To discover new concepts:	
	Visual nature/Sf-d-vn	With the DGS, the teacher introduces new concepts, exploring their visual nature
	Numeric nature/Sf-d-nn	With Scilab, the teacher introduces new concepts, considering their numerical nature
	To clarify theoretical aspects:	
	Visual nature/Sf-cl-vn	With the DGS, the teacher consolidates and clarifies concepts, exploring their visual nature
	Numeric nature/Sf-cl-nn	With Scilab, the teacher creates opportunities to consolidate concepts, considering their numerical nature
	To calculate:	
	Time saving/Sf-ca-ts	Students and teacher use Scilab to facilitate auxiliary calculations
	Complexity of calculations/Sf-ca-cc	Students use Scilab in solving tasks, given the nature of the calculations to be performed
	Verification of results/Sf-ca-vr	Students and teacher use Scilab to check results previously obtained
	To anticipate/Sf-a	The teacher uses different software to anticipate some concepts
Attitudes	Initiative/A-i	The students, by their own initiative and autonomously, resort to Scilab
	Enthusiasm/A-e	The students demonstrate some degree of satisfaction with the work done or results achieved
	Appreciation/A-a	The teacher seeks to promote the use of Scilab, highlighting some potentialities
	Discouragement:	
	Time expenditure/A-d-t	Expectations are diminished by the time spent more than expected
	Implementation difficulties/A-d-i	Expectations are diminished by technical difficulties
	Errors in using Scilab/A-d-e	Expectations are diminished by students' errors in use of Scilab

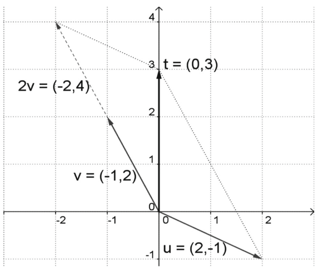
The following subsections analyze the different emerging categories, including some evidences captured in MNs.

3.1 "To Discover New Concepts" and "To Clarify Theoretical Aspects"

These categories are located in the moments before and after the concepts are formalized. In the first case, they are coherent with the strategy outlined to try to introduce the new concepts of linear algebra from concrete situations and the students' previous knowledge. As for the second case, "to clarify" means to consolidate or exemplify. The relevance of the teacher's use of the different software programs is justified by helping in the interpretation and understanding of processes (numerical or visual exploration) and not by obtaining products (merely performing calculations).

The teacher used GeoGebra and Mathematica as DGS to introduce the concept of linear combination of vectors. In an early moment, the teacher related this concept with the resolution of systems of linear equations with two and three unknowns. In GeoGebra, the teacher built a figure with vectors with two coordinates, representing the coefficients of the unknowns and the independent terms. Next, he showed how the vector associated with the independent terms could be obtained from the others, including in his discourse the designation linear combination of vectors (Table 2). In this way, determining the solution set of a system of linear equations would be the same as finding the scalars that allowed writing the vector of the independent terms as a linear combination of the vectors associated with the unknowns.

Table 2. Evidences in MNs of category "to discover new concepts".

Evidences	Category
 "Are you seeing, for now, what is the format of a linear combination? It is to have a vector that can be obtained at the expense of others, provided that ... what? If you multiply the others by any scalars, which can be determined to give that vector," I concluded.	Sf-d-nv
Turning the figure, it became clear that the vectors were on the same plane. "So, geometrically, what happened? If one of the vectors is written as a linear combination of the others, do they have to be on the same plane or not?" "Yes," replied Juliana.	Sf-d-nv
"This is what we know ... Scilab did the multiplication and gave this," I said, pointing to the result of the multiplication that was projected. I continued, avoiding the possibility of multiplying only homologous elements.	Sf-d-nn

Similarly, in Mathematica the teacher represented vectors with three coordinates, in the context of solving systems of linear equations with three unknowns. He created the opportunity for the students to deduce the relative position of the vectors (same plane) when one vector is a linear combination of the others. It became possible to develop the geometric intuition of whether one vector could be written as a linear combination of others before the concept was formalized.

For the matrix multiplication approach, the resolution of an initial task was proposed to the students. From the result obtained in Scilab of the multiplication of two matrices, it was intended that the students deduce the row-column multiplication method, based on the concept of inner product (Table 2).

The students were able to deduce an algorithm for matrix multiplication only with great help from the teacher. However, the strategy had some advantages. The early presentation of the result obtained in Scilab made it possible to establish that multiplication was not done by multiplying homologous elements and that matrices could have different sizes (Sf-d-nn).

The study of systems of linear equations began with a review of the methods already known to the students and the discussion of their limitations when the number of equations and unknowns increases. In one case, involving systems of linear equations with two and three unknowns but with more equations than usual, students were able to classify different systems of linear equations based on their geometric representation (Table 3). Through visualizations in GeoGebra and Mathematica, the students realized that the only difference was the increase in the number of lines or planes.

As a complement, the teacher guided the students to use a Scilab command that indicated only a single solution of a system of linear equations, although the students visualized in Mathematica that all planes representing the equations intersected a line. Without solving with pencil and paper, the combined use of Scilab and Mathematica allowed the students to deepen the sense of particular solution and general solution of a system of linear equations.

Definitions of a matrix in echelon form and reduced echelon form were introduced along with the basic definitions on matrices. Later, when the teacher introduced Gauss and Gauss-Jordan elimination methods, Scilab highlighted the differences between those definitions.

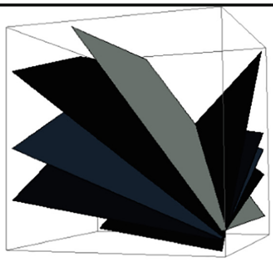
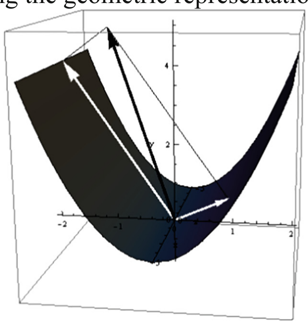
When students applied the *rref* command, the obtained matrix was equal to that obtained by the teacher. The comparison of results helped to clarify that in reduced echelon form a matrix was unique and that the same was not true in the case of the echelon form of a matrix.

With regard to the concept of a subspace of a vector space, the teacher first explored the analytical nature of the concept. The use of Mathematica complemented the approach. It was observed that, for each set represented, the students were able to validate the different axioms, thus deepening the geometric interpretation of the concept.

3.2 "To Calculate" and "To Anticipate"

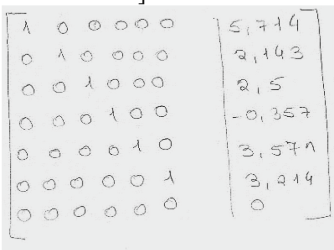
The calculations supported by the use of Scilab were carried out mainly by the students but also by the teacher. The Sf-ca-ts category reflects the teacher's choice to suggest this software to make some solutions faster. This happened in exercises related to the

Table 3. Evidences in MNs of category “to clarify theoretical aspects”.

Evidences	Category
 I began by asking the number of equations: “Five,” answered the students. “Believe it!” Juliana reacted immediately. [...] I then circled the figure in Mathematica and the students said that the planes intersected one line and that the system of linear equations would be consistent, with many solutions. […]	Sf-cl-nv
After saying the command for solving the system of linear equations (A\B), the students were saying the solutions obtained. [...] I established that in these cases we were only finding particular solutions.	Sf-cl-nn
Returning to Scilab, I presented the final result, highlighting the command used, *rref*, and I mentioned that the reduced echelon form found was unique.	Sf-cl-nn
I began by showing the geometric representation of the set:  “Go through zero, over there!” said Helder immediately, after I pointed out the origin of the referential.	Sf-cl-nv

concept of linear combination of vectors (Table 4). Here, the resolution of a system of linear equations is an auxiliary calculation. What matters is that students conclude quickly whether or not the associated system of linear equations has a solution. It is also no longer the time for the teacher to assess whether or not students can apply Gauss and Gauss-Jordan elimination methods by hand to solving systems of linear equations.

Table 4. Evidences in MNs of categories "to calculate" and "to anticipate".

Evidences	Category
When Juliana asked me if they had to solve the system of linear equations by hand, I said I would use Scilab to be faster.	Sf-ca-ts
In the meantime I went through Group 6, where Juliana, who was already calling me some time ago, showed me the matrix in reduced echelon form [obtained in Scilab]. 	Sf-ca-cc
Then I asked the students to find the equivalent matrix autonomously. [...] while the students continued the resolution, I wrote the initial matrix in Scilab, with the purpose of confirming the result.	Sf-ca-vr
I informed the students that at the moment they could only recognize if a given matrix was written in echelon form or reduced echelon form and that at a later time they would learn to perform the calculations, just as Scilab did.	Sf-a

The resolution of some realistic applied problems in the classroom justified the use of Scilab for calculations that became more complex (Sf-ca-cc). In one example, for the determination of the intensities of an electric circuit, students had to solve a system with seven equations and six unknowns (Table 4). Rather than the nature of the scalars, it is the "size" of the system of linear equations to solve that confers such complexity.

The teacher sought to highlight the process of verification of results, an action reflected by the category Sf-ca-vr. The performance of matrix operations, the demand for the reduced echelon form of the matrix and the determination of the inverse of an invertible matrix were the contents from which this category emerged. In these cases, it is particularly relevant for students to acquire pencil-and-paper solving skills. As a next step, the comparison of the results obtained with those obtained in Scilab made it possible to give this software program the role of regulator.

Scilab facilitated the work of the teacher in cases where the concepts were approached early, allowing some results to be obtained before they were taught. From this action emerged the category Sf-a. When the teacher explored the definitions of echelon form and reduced echelon form of a matrix, he turned to Scilab for examples of reduced echelon matrices. With the same command in Scilab, but with augmented matrices of systems of linear equations, the teacher led the students to obtain equivalent matrices that allowed them to come to conclusions regarding the respective classification of the system of linear equations (this still before the students learned Gauss and Gauss-Jordan elimination methods).

3.3 "Attitudes"

The initiative to use a computer and different software programs and the enthusiasm for the results obtained were two behaviours revealed by the students (categories A-i and A-e, respectively).

Due to the habit of using Scilab to perform matrix operations, when the teacher was presenting the Gauss and Gauss-Jordan elimination methods, students immediately asked him if they could use Scilab. It was in the use of these procedures for solving systems of linear equations that students most recognized the importance of using Scilab. When the statement was omitted or when the teacher said nothing, the students asked whether or not they could use Scilab. The initiative was also greater when students recognized the realization of more complex calculations or when investigating the possibility that one vector could be written as a linear combination of others, as shown in the excerpt in Table 5.

Table 5. Evidences in MNs of categories "initiative", "enthusiasm", "appreciation" and "discouragement".

Evidences	Category
Meanwhile, I heard a comment from Fernando to a colleague who caught my attention: "Oh! ... that I'll do with Scilab! Do you think I'll do all the computations by myself?"	A-i
In the meantime, I observed in Group 6 the enthusiasm over the achievement in Scilab of the matrix in reduced echelon form and soon showed to students of other groups the result that they had obtained.	A-e
I have repeatedly conveyed the importance/ I reiterated the recommendation/ I reiterated the potentialities [of software use at the level of]: • Geometric interpretations; • Algorithmic procedures; • Classroom situations; • Situations of study; • Help in solving exercises; • Verification of results (in class and at home); • Time-saving solution.	A-a
Errors in the writing of the linear equations and transcription errors of the augmented matrix in Scilab dictated the obtaining of matrices in reduced echelon form that corresponded to inconsistent systems of linear equations. I even tried to identify some of the mistakes, until I decided to tell the groups to come up with a response coherent with the kind of matrix they got.	A-d-e

It was also in the resolution of a system of linear equations, but with seven equations and six unknowns, that the students expressed for the first time enthusiasm for the use of Scilab. Faced with a large matrix and the achievement of the "1's all aligned" (reduced echelon form), the teacher observed that the first students to succeed began to show the result to their close colleagues, with evident enthusiasm.

The A-v category emerged from the teacher's interest that the students recognize the importance of using computers in linear algebra classes (and even outside!). He often talked to students about potential benefits and cases where such use was justified (Table 5). In terms of processes, the teacher widely sought that students see Scilab as the "friend" who helps and validates the solutions of the exercises. In terms of contents, the teacher valued the use of Scilab in operations with matrices, in solving systems of linear equations and in calculating the inverse of an invertible matrix.

The categories associated with discouragement (on the part of the teacher or the students) reflect possible setbacks or unmet expectations regarding the use of the computer and software in linear algebra classes.

The A-d-t category caused disappointment to the teacher because it corresponded to moments that broke the pace of the lesson and during which the teacher was not actually teaching linear algebra (or students learning). In this context, many doubts expressed by students about how to use Scilab were highlighted.

With regard to the A-d-i category, the teacher also had to struggle with the absence of computer rooms (and students who did not always bring their laptops) and the lack of licenses (reducing the role of Mathematica, as students could not use it as CAS, nor as DGS). The students sometimes did not demonstrate the most appropriate attitude, using the computer for purposes not related to the class.

Finally, the A-d-e category emerged from aspects not anticipated at the beginning. It was observed that in some cases an error in the use of Scilab compromised the achievement of a correct answer, mainly due to transcription errors.

4 Discussion and Conclusion

The experience of teaching linear algebra based on the recommendation of the literature to consider the use of technology [1] forms part of this study. The construction of the MNs of some classes made it possible to know the teacher's actions and the reactions and attitudes of the students regarding the use of the computer and CAS and DGS software programs.

The topics of linear algebra recorded in MNs were: operations with matrices, solving systems of linear equations, determination of the inverse of an invertible matrix, definition and validation of subspace axioms of a vector space and linear combination of vectors. The content analysis of MNs led to the identification of a set of categories, divided between the use that can be made of those software programs (sub-dimension *Software function*) and behavioural aspects observed in the teacher and students (sub-dimension *Attitudes*). With regard to those topics and from the analysis of the categories (Sect. 3), conclusions can be reached on how CAS and DGS can function as beneficial tools in teaching and learning linear algebra.

Based on some works already known [5, 6], the present study has verified that the DGS enabled making some concepts of an abstract nature more concrete, such as those of linear combination and subspace of a vector space. This occurred through the development of geometric interpretations, taking advantage of the kinesthetic nature of that type of software. This option can be considered either in moments prior to its formalization or in later moments, to consolidate, clarify or exemplify. DGS can still be considered for concepts where, apparently, the focus is on the analytical part. In the case of this study, Mathematica helped the teacher to establish the limitations of the graphing method (and to justify the learning of the Gauss and Gauss-Jordan elimination methods) and to interpret geometrically the solution of a system of linear equations. Solution by the graphing method is possible only with systems of linear equations containing up to three unknowns. In this case, without the help of this type of software, it would be very difficult to draw planes in three-dimensional space.

As for the CAS, in this particular case, for Scilab, the main function was to provide support in performing calculations. However, CASs can also be considered to introduce and clarify concepts, according to their numerical nature, or to anticipate issues not yet addressed. Whether in the teaching and learning of linear algebra there are more opportunities to consider CAS or DGS is not discussed here. The prevalence of references to CAS in this text is due to the fact that the students used only Scilab, resulting in a greater recording of evidences regarding the use of this type of software.

In the literature, the use of CAS to solve realistic applied problems [1, 3, 4] is assumed to be due to the complexity of the calculations involved. This study has also extended the usefulness of CASs to the verification of results and to the faster solution of different types of tasks. In this particular case, one of the functions of technology already identified in mathematical education has been applied to linear algebra: "the tool function for doing mathematics, which refers to outsourcing work that could also be done by hand" [22, p. 3].

The categories of the sub-dimension Attitudes provide clues to reinforce the status of CAS and DGS as beneficial tools for the teaching and learning of linear algebra, for the positive attitudes observed in students, such as initiative and enthusiasm. They also give clues as to how to increase their potential. We emphasize (1) the teacher's role in developing the use of these resources by students and in overcoming the obstacles, and (2) the effort and the actions of the teacher to optimize its use in the classroom (avoiding wasted time) and to make sure that the students maintain a positive attitude when using the technology.

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Exploratory Potentialities of Emerging Technologies in Education

Improving EFL Students' Writing with the Help of Technology: The Case of Verb Tenses in Secondary Education

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Abstract. This article reports on a research project carried out to detect and correct tense mistakes that students, who learn English as a Foreign Language, tend to make in their free written production at the stage of secondary education. While writing their compositions, learners mainly locate events along a timeline by means of verb tenses. However, failing to provide the right tense may distort the meaning of their written compositions. These mistakes can be considered semantic mistakes as they are related to the meaning of the word in context. Semantic mistakes are generally difficult to detect either by Self-revisions made by students or even when there are "guided revisions" led by some computer applications. At the moment, commercially available grammar checkers cannot detect and help with these mistakes because they are not capable of analyzing the context of the text from a semantic point of view. Currently available software will consider that the sentence *"I like jam"* is correct even if the student wanted in fact to say *"I liked jam"*. This investigation reports on the use of Tense Buster, a prototype software especially designed by the authors to detect mistakes in the verb form and provide feedback to the students to Self-correct and learn from their own mistakes. This paper, based on the analysis of the Self-corrections in 132 essays of Spanish students (from A1 to B2 European guideline levels), justifies the potentiality of the Tense Buster to help them improve their Free-Form written production and paves the way to the deeper understanding of the student performance within the specific learning context.

Keywords: Verb tense mistakes · TB grammar checker · Educational data machine learning · Corrective software · EFL writing

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1 Introduction

Nowadays, Computer-Based tools have become commonplace in the teaching/ learning scenario in Spain at the secondary level. The use of specialized software is not only suggested by teachers in all domains but also demanded by young students often considered "digital natives", a term coined and popularized by education consultant Marc Prensky in 2001 [1]. According to Prensky, digital technology has changed the way students think and process information and they require a Media-Rich learning environment to hold their attention and help them succeed academically. Consequently, it is quite common that teaching plans for secondary education, include some sessions where students are asked to use Computer-Based tools that will intervene in the teaching/learning process and adapt to the curriculum. Focusing on the teaching and learning of foreign languages, specifically English as a Foreign Language (EFL) and the development of writing skills, students should have access to Computer-Based tools that help them improve their free written production. Error[1] detection and error correction have recently been researched for the development of writing skills in various teaching contexts [3–7]. Despite the huge efforts made in the field of Information and Communication Technology (ICT), few reliable pedagogic grammar checkers have been developed to help students correct and learn from their own mistakes, one of the most reliable tools being Grammar Checker, developed at the Universidad Nacional de Educación a Distancia, UNED[2]. There are some types of mistakes in Spanish students' compositions that cannot be detected by currently developed Computer-Assisted writing software [8]. They are the "tense errors" that Non-native EFL students make in their written texts at the stage of secondary education [9]. Learners generally locate events along the timeline by means of the verb tenses and any mistakes in this respect will distort the meaning of their compositions and will produce communication breakdown. A learner written corpus was specifically compiled for this investigation [10] and, as a way of example, some tense errors were found such as *we went to Italy on boat and we ∗have a very good time there*. In this case, the student made the mistake of using the form ∗have rather than had. Other similar examples are: *The last time I ∗go to Morocco* (the correct form would be *The last time I went to Morocco*); *In summer I ∗go to Barcelona to visit my grandparents* (the correct form would be *In summer I went to Barcelona to visit my grandparents*). These are semantic errors that are hardly ever detected by specialized software like Microsoft Word grammar checking facility. The mistakes quoted above are not spelling mistakes and would therefore be correct in another context at the word level. This is the reason why currently developed software cannot discriminate it. These errors can go unnoticed both in the Non-guided revisions that students make of their

[1] Decisions about exactly what constitutes an error are notoriously complex and sometimes subjective (see for example the discussion in Lennon 1991 [2]). The definition of the type of error studied in this research could be "anything which an English teacher would mark as wrong regarding the verb phrase".

[2] https://www.youtube.com/watch?v=l18Lcr7CvzE.

compositions and in the revisions that some grammar checkers make [11]. In the case of grammar checkers, they are unable to interpret the context and warn the student about semantic errors. With current technology, a computer is unable to assure whether in the sentence *In summer I ∗go to Barcelona*, the student meant *I go* or *I went*. Therefore we are dealing with a type of error that only the human eye can detect with absolute accuracy. In this scenario, previous research work [11–13] has been implemented by the authors to design the Computer-Based programme namely Tense Buster (TB) that can help students detect their tense mistakes in a Media-Rich learning environment. In [11] author concluded that Spanish EFL students are capable of correcting "tense errors" when their attention is focused on the verb form directly and if some specific pedagogic feedback about the form is offered. Consequently, the positive effects of formal teaching on the apprentice's Inter-language [14,15] have been considered in the design of TB, to make students aware of their "tense errors" in their Free-Form compositions. "Tense errors" are often competence errors arising from misconceptions about verb tense and aspect differences [16,17]. Students might benefit from feedback that addresses the underlying problem rather than simply suggesting the correct tense [5]. In this sense, TB will help students with a twofold function; on the one hand, verb tenses are highlighted to call student writers attention and, on the other hand, pedagogic ad hoc feedback is given on common tense misconceptions. A frequent "tense errors" database has been added to TB to detect and flag the impossible combinations found in students compositions and explains why a verb tense is wrong. As these are real errors previously identified in students compositions, they are the type of "tense errors" that generic Parser-Driven grammar checkers cannot detect. Students sharing a mother tongue tend to make the same type of errors over and over again and that makes it valuable to incorporate real errors in the database [18]. Tests indicate that such Easy-To-Build tense checkers might become a useful tool for EFL learners, and, along with other recent technological developments, suggest that student Self-correction of compositions (including grammatical and lexical errors as well as spelling errors) is becoming increasingly feasible [5], and it is clear that considerable progress is being made in the field of digital feedback in learner writing [3]. This work reports on the experimental use of the TB based on the analysis of the Self-corrections in 132 essays of Spanish EFL students (from A1 to B2 European guideline levels). The research questions **(RQ)** of this research design were:

RQ1: Did the TB help the students to be aware and correct their mistakes in verb tenses in their English written texts?

RQ2: How can machine learning approaches upon data collected by the TB can contribute to the deeper understanding of the student performance during the above task?

2 The Tense Buster Prototype

TB can be described as a software especially designed to give students an active role in the detection and correction of tense mistakes that will allow them to improve their knowledge about the use and form of tenses. TB is a prototype intended for EFL learners, to be used individually in the error correction process that usually takes place after writing a Free-Form composition in a classroom context. Students just paste or type their compositions in TB and let the programme, first, detect all “the verb tenses” in the text as well as any “frequent tense errors” that are expected in the learner Inter-language development at the A1-B2 level; second, TB provides specific pedagogic feedback that will help students correct any possible “tense errors”. Consequently, TB can be used as a tool that will help students filter their compositions before handing them in to the teacher for a revision of other writing aspects such as style, specific expressions, or word order. TB first function, the detection of “verb tenses” and “frequent verb errors”[3], is executed once students paste or type their composition in TB and click on “Detect Verb Tenses”. On the one hand, TB highlights all conjugated verb forms in three colors according to the verb tense they belong to: present tense in green, past tense in blue, future tense in pink. For example, in the sentence *The last time I went on holiday* (see Fig. 1, line 7 of the paragraph), the verb **went** is highlighted.

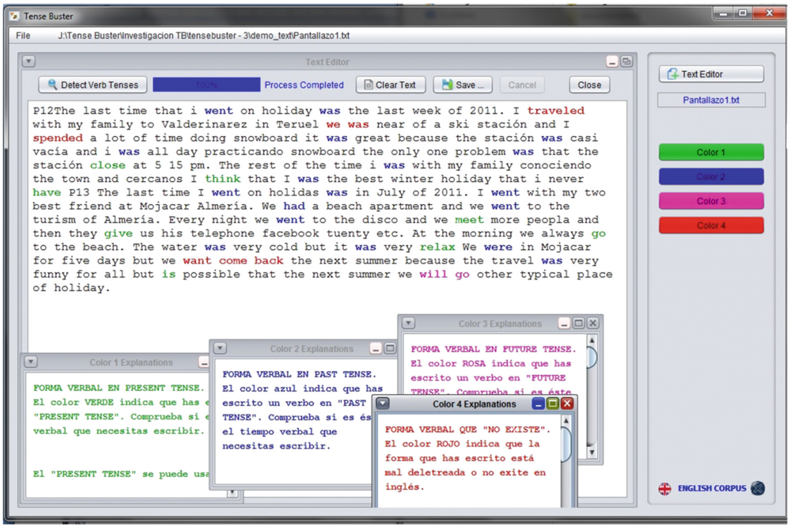


Fig. 1. Detection of “verb tenses” and “frequent tense errors” in a student’s composition and Pop-up windows. (Color figure online)

On the other hand, TB provides specific feedback about the “frequent verb errors” that TB highlights in red. For example the verb phrases **we was,* **I*

[3] The concept “frequent verb errors” includes any errors of any kind in the “verb phrase” that can lead to a misunderstanding and that an English teacher would correct to a learner: spelling errors, lack of a preposition, lack of the gerund form, etc.

*spended, *I traveled, *we want come back* (see Fig. 1) are highlighted in red because they have been added manually to the category impossible forms. If students cannot correct the mistakes highlighted in red, they can click on the red button in the menu and a window will pop up with specific feedback that will help them with the correction. In this first prototype, comments will appear in alphabetical order in the same window, but ideally the feedback should be given when the students click on the expression and a single window pops up with the information about that expression. Below you can see an example of the feedback given:

- traveled > Remember that verbs ending in *l* double it when we add - ed: *travelled*
- we was > Remember that we say *we were*, we only use was for *I, he, she, it.*
- spended > Remember the difference between regular verbs (*play* > *played*) and irregular verbs (*go* > *went*; *spend* > *spent*).
- we want come back > Remember that the verb "want" is followed by the preposition "to" > *I want "to" come back.*

3 Empirical Research

The effectiveness of TB was tested in: (a) raising Spanish EFL students' awareness of their mistakes in verb tenses and towards enhancing their ability to correct them in their English written texts; and, (b) informing the teacher about deep characteristics at the Micro-level of the students performance concerning the verb tense use and the relevant errors.

3.1 Methodology

The performance of secondary education students who used TB to check the past tense of their Free-Form written compositions was studied through a Quasi-experimental setup. This research studied the performance of secondary education students who used TB to check the past tense of their Free-Form written compositions.

The participants were students from the 1^{st} to the 4^{th} year of Secondary Education, who studied in a Spanish school located outside of the city of Murcia, Southeast of Spain, in a rural area. The school teaches students in the following range of ages: 3 to 5 (Kindergarten), 6 to 11 (Primary school) and 12 to 16 (Secondary school). In total there are about 400 students that come from small towns near the school and study EFL from the age of 6 to 16. Most of the participants in the research have the Spanish nationality but some of them come from other countries such as Morocco, Romania, England or Venezuela, and they were incorporated to the Spanish educational system at different stages. Although the variable sex has not been taken into account at any time throughout the study, it could be mentioned that both sexes were equally represented in the sample studied. The participants' level of English was between A1 and B2 and their instruction on the subject English as a Foreign Language along their primary and secondary education has followed the Spanish curriculum which is divided in the four main communicative skills: listening, speaking, reading and writing. In the case of writing skills, classes focus mainly on grammar and spelling mistakes, use of connectors, paragraph development, parts of the text, types of texts, comprehension/production strategies, sociocultural aspects and vocabulary. A common practice in the classroom is to ask students to write compositions to develop their communicative skills.

In order to test the effectiveness of TB, a classroom activity with four groups, namely 1st ESO[4] to 4th ESO, of secondary education students from the relevant, 1^{st} to 4^{th} years, was planned. In their English lesson, students were asked to type three compositions on a computer about three experiences in the past: (1) the last time you went on holidays, (2) the last time you went to the cinema, (3) the last time you went shopping. They were written in the second and third term, between February and April 2017. For each of the compositions, a Two-Session procedure was followed:

– Session 1: In the ICT classroom, Students, individually, typed their texts in their computers and shared them with the teacher through google docs. They were allowed to use the internet dictionary *wordreference*[5] for vocabulary. They had 55 min to complete the activity.
  After session 1, the researcher copied and pasted the original compositions in TB and, first, trained TB to detect and highlight all the verb forms according to 4 categories (green for present tense, blue for past tense, pink for future tense, red for impossible combination[6], see Table 1); second, all the tense mistakes were classified into 4 categories: present tense errors, past tense errors, future tense errors; other tense errors (see Table 2). To make this process easier for the researcher, in a research version of the TB four more options to append and classify tenses errors in a "right click" list were added in the main desk pane. This version of TB also had the "print statistics button" to display the related statistics about tense used and tense mistakes.
– Session 2: In the ICT classroom, TB was introduced to the students as a tool that helps them detect and correct mistakes in verb tenses. They saw a few examples of how to revise and correct tense errors in compositions written by EFL students. After that explanation, students had 55 min to copy and paste their compositions on the "enriched" prototype version of TB, to activate the detect verb tenses button and to correct any possible tense mistakes. After using TB, students shared their composition with the teacher through "google docs" to analyze any corrections and/or changes in the original text.

[4] The Spanish Compulsory Secondary Education stage includes 4 school years and are usually referred to as ESO.
[5] http://www.wordreference.com/.
[6] These categories were coded as Color 1 (C1); Color 2 (C2); Color 3 (C3); Color 4 (C4).

Table 1. Classification of all the verb forms into four categories.

Tenses categories	Example
Present tense: Color 1 (C1)	have been; give; gives; finish; ...
Past tense: Color 2 (C2)	accepted; arrived; asked; ate; ...
Future tense: Color 3 (C3)	will go; will show; will enjoy; will fight; ...
Impossible combinations: Color 4 (C4)	will goes; went visited; I'm go out; buyed; couldn't did; ...

Table 2. Classification of all the tense errors into four categories.

Tense error categories	Example
Present tense errors: Error Color 1 (Err C1)	- he often *go to ski - i *recommended you - he *have got a small cat - he *have got a amazing graphics - ...
Past tense errors: Error Color 2 (Err C2)	- I *spended a lot of time - we *meet more people - they *give us his telephone - we always *go to the beach - ...
Future tense errors: Error Color 3 (Err C3)	I *repeat this experience with my friends
Other tense errors: Error Color 4 (Err C4)	- Me *like return - *like to repeat it - I would *like repeat

After session 2, the researcher reviewed all the compositions and repeated the classification of the verb tenses (Table 1) and of the tense mistakes (Table 2) with the help of the research version of TB.

3.2 Data Collection

This section presents the elaboration of student's essays and the process to transform them into valuable data. Since the research protocol depicts two periods, i.e., the "Pre-phase" where students have not yet seen the TB tool and the "Post-phase" where students have acquired familiarity in utilizing the tool in the educational process, the data collection was splitted in two phases. Both phases contain the same data collection variables. Table 3 provides the list of variables that were monitored during the data collection process.

Table 3. List of variables and their descriptions. Each record refers to a candidate essay.

Variable	Description
$fc1, fc2, fc3, fc4$	Frequency of color 1, 2, 3, 4 verb tense respectively
$ferc1, ferc2, ferc3, ferc4$	Frequency of color 1, 2, 3, 4 verb tense error respectively
TP	Sequence of verb tenses patterns
ETP	Sequence of verb tenses error patterns
$TPETP$	Sequence, of tenses & verb tenses error patterns

Table 4 illustrates a sample of the collected variables and the corresponding records from a student's essay.

Table 4. A sample of a student's essay and the corresponding records.

Variable	Value
$fc1, fc2, ferrc2$	1, 4, 7
TP	C2, C2, C2, C1, C2
ETP	E2, E2, E2, E2, E2, E2, E2
$TPETP$	C2, E2, E2, E2, E2, C2, E2, C2, E2, E2, C1, C2

In addition to the above list of variables we have also collected the erroneous verb expressions. These are sentences segments that identified in student's essays, annotated and classified manually through the graphical user interface of the TB tool in the appropriate verb error tense category. Table 5, illustrates a sample of these expressions.

Table 5. A sample of erroneous expressions.

Error type	Example
Error type c1	*he have got a amazing graphics*
Error type c2	*I stay in many famous restaurants*
Error type c3	*I repeat this experience with my friends*
Error type c4	*I would like repeat*

The dataset consisted of 132 essays in the "pre" and "post" phase, including 78 words on average in each phase, respectively. Next, a detailed description of the data analysis and evaluation of the experimental setup is presented.

3.3 Data Analysis

In this section appropriate designed analysis upon the collected dataset from the "pre" and "post" phases is presented. This analysis extends from simple statistics to a combination of advanced machine learning methods, in order to provide an In-depth analysis which aspires to extract information at different levels of granularity.

Preliminary Analysis. In this analysis all variables that contain the frequencies of the verb tenses and the verb tense errors in Table 3 were employed and simple statistics were calculated, i.e., a box plot for each candidate variable. Such statistic provides information about the upper value, the lower value, the standard deviation as a "box" and finally the median value as a "bold line" inside the "box". Small dots, the "outliers", depict the values that extend outside the normal distribution of a candidate variable analysis. Figure 2 presents the results of the analysis of these variables for each ESO level in the "pre" and "post" phase of the TB tool use.

Building Semantic Networks. In this subsection the analysis of the corpus of the verb tenses erroneous expressions from a linguistic scope is presented. Since such expressions have been identified, classified and collected during the data collection process we rely on them to explore linguistic or semantic patterns that would reveal meaningful relations among the elements that these expressions constitute. The process was implemented as follows. Initially the corpus of the verb tense erroneous expressions was employed and the natural language toolkit [19] was applied to transform them into part of speech tokens. These tokens are labels that substitute the elements of an expression. Table 6 shows a sample of such elements substitution.

Table 6. A sentence sample and the POS tag substitution.

I	Stay	Always	In	Beautiful	Beaches
NN	VBP	RB	IN	JJ	NNS

Since the purpose of this study is to reveal grammatical weaknesses in the process of learning a second language, these sequences were handled as semantic mappings. All these mappings were collected and elaborated considering each element of the sequence (POS tag) as an individual semantic structure and N-gram semantic structures that ultimately reveal meaningful semantic patterns were explored. Furthermore, the notion of the transition between these N-gram

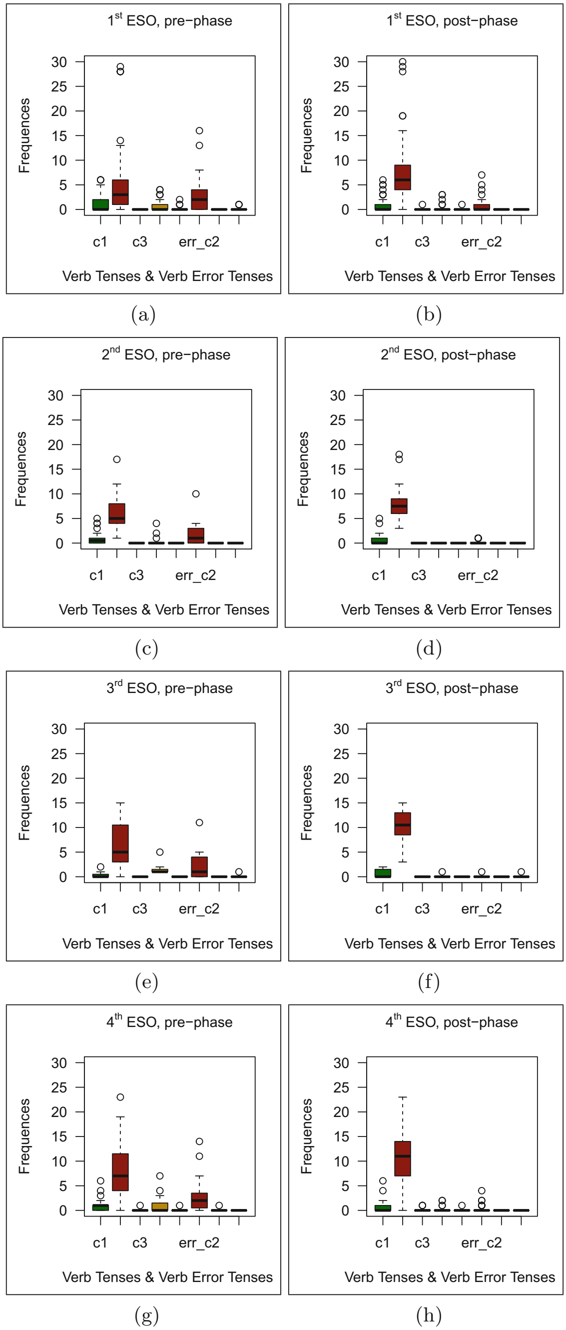


Fig. 2. Statistics of the verb tenses and the error's verb tenses in the "pre" and "post" phase for each ESO respectively (1st ESO (a), (b), 2nd ESO (c), (d), 3rd ESO (e), (f), 4th ESO (g), (h)). Colors change according to the tenses. (Color figure online)

elements was adopted (the source transition and the target transition). For example, in the pattern "NN-VBP-RB-IN-JJ" the subsequence of labels "NN-VBP-RB-IN" was named source transition and the label "JJ" target transition. Both source and target transition labels constitute a semantic pattern. By adopting this notion, apart from meaningful subsequences also dependency semantic structures can be identified, which after an additional elaboration reveal the network of patterns. Finally, an open source network analysis platform [20] elaborates the network of patterns to visualize, produce statistics and create appropriate clusters, i.e., patterns that interact in such a manner that constitute a "community". These clusters were created implementing a modularity analysis algorithm (embed in toolkit [20]) for detecting communities in networks. In our case these clusters reveal a central POS tag that behaves as a central node in this community. POS tag labels and descriptions are presented in Table 7. The variable "In-degree" in this Table, refers to the total amount of inbound POS tag patterns relations, i.e., the amount of inbound transition information that goes through this POS tag. From the corresponding value the POS tags that consume most of the linguistic expressions in the corpus of error's expressions can be inferred.

Table 7. List of POS tags elements identified in the semantic network and the In-degree value.

Node	Description	In-degree	Node	Description	In-degree
NN	Noun, singular or mass subject?	200	CD	Cardinal number	54
DT	Determiner	193	VBD	Verb, past tense	40
IN	Preposition or subordinating conjunction	177	CC	Coordinating conjunction	38
PRP	Personal pronoun	144	NNS	Noun, plural	36
JJ	Adjective	136	VBG	Verb, gerund or present participle	32
TO	to	110	VBZ	Verb, 3rd person singular present	26
VB	Verb, base form	96	VBN	Verb, past participle	23
VBP	Verb, NON-3rd per- son singular present	90	POS	Possessive ending	19
RB	Adverb	55	RP	Particle	13

Building Trees. A decision tree can be applied in several problems mainly regression or classification. Our work embeds the classification prediction. Tree based methods involve stratifying or segmenting the predictor space into a number of simple regions. In order to make a prediction for a given observation we use the mode of the training observations in the region to which it belongs. Since the set of splitting rules used to segment the predictor space can be summarized in a tree, these types of approaches are known as decision tree methods. The process of building a classification tree can roughly be described as follows:

1 The predictor space - that is, the set of possible values for $X_1, X_2, \cdots, X_p$ is divided into J distinct and Non-overlapping regions, $R_1, R_2, \cdots, R_J$.
2 For every observation that falls into a region R_J, a prediction counting on the majority class is made. That is the class that has the most observations in that region.

As an example, let us assume we have three prediction classes blue, red, green and an observation falls into a region that contains the observations $(30, 15, 5)$ about the prediction classes. The predictions in that region are $(0.6, 0.3, 0.1)$ for blue, red, and green respectively. So, we infer that the candidate observation is blue with probability 60% in that region.

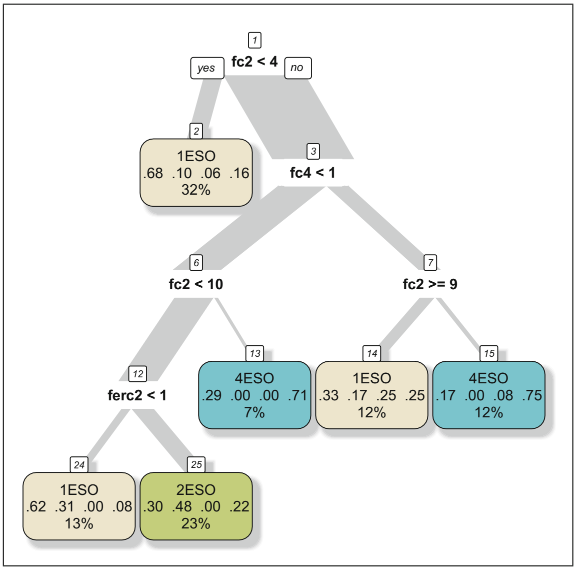
Building trees is a class of supervised learning method that finds Non-linear solutions to the variables of the predictor space. As in every supervised method, the candidate dataset is split into a training and a testing phase. In the training phase, algorithms analyze a given set of "training examples" (75%) and build a model. In our case, that would be a set of pupils with their features representations (predictor space) and the information (prediction classes) the level they belong i.e., 1st, 2nd, 3rd, 4th ESO level respectively. The testing examples (25%) exploit the model to validate the predictions.

For the purposes of the present study two classification trees were created (Fig. 3) [21]. The frequencies of the verb tenses $(fc1, fc2, fc3, fc4)$, and the frequencies of the verb tenses error's $(ferc1, ferc2, ferc3, ferc4)$ were utilized as a predictor's space and the $1^{st}, 2^{nd}, 3^{rd}, 4^{th}$ ESO levels as the prediction classes. The purpose of this analysis was to extract rules that will provide relations between the features and the classes (i.e., guessing what features meets a student belonging to a certain grade and vice versa). Table 8 provides the confusion matrix of the testing phase, a metric to evaluate the quality of the predictions of the classification trees (e.g., if the accuracy of a tree model and the accuracy of the confusion matrix is close we may safely infer on the validity of the extracted rules).

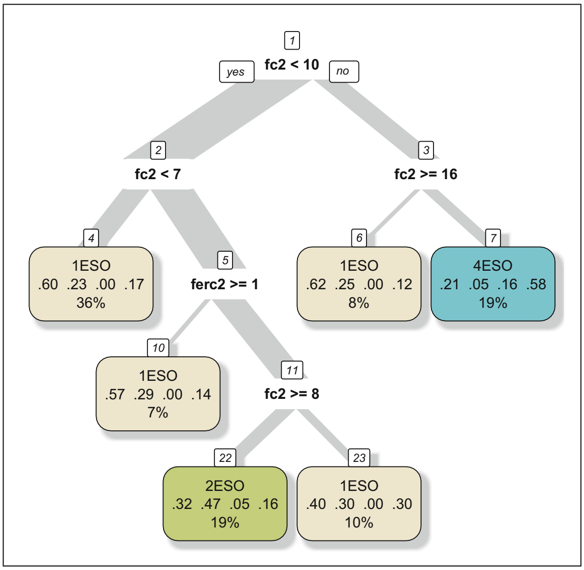
In Table 8 the confusion matrices present metrics produced from the validation of the testing data on the model for each class individually. Since we have four prediction classes a random choice algorithm would provide F-score 25% for each class respectively. Having this value as a baseline we extract only meaningful rules from the two classification trees. These are rules for the 1^{st} ESO, 2^{nd} ESO in the "pre" phase and 1^{st} ESO, 4^{th} ESO in the "post" phase. Table 9 provides the most important extracted rules from the two classification trees.

4 Discussion

Towards answering to the research questions, in this section the results of the three approaches to the data analysis are discussed. In particular, From Fig. 2(a) in the preliminary analysis, it can be noticed that the *c2* was the most used tense, as it was expected (descriptions of actions in the past). Moreover, the frequency of errors was the highest in the relevant category *err_c2*. From Fig. 2(a),(b) it can be noticed that the *c2* was increased in the "post" phase of the TB tool use.



(a)



(b)

Fig. 3. The classification trees and the relations between the prediction space and the prediction classes. Under the labels, the numbers represent the probability of ($1^{st}, 2^{nd}, 3^{rd}, 4^{th}$) ESO Level respectively. (a) The classification tree in the "pre" phase. (Model Fit 59.18%). The percentage expresses the portion of the data that "follow" the path. (b) The classification tree in the "post" phase. (Model Fit 55.10%). The percentages express the portion of the data that fall into that label.

Table 8. Confusion matrices of the test sets on the models of the two classification trees.

	"pre" phase				"post" phase			
	Precision	Recall	F-score	Acc.	Precision	Recall	F-score	Acc.
1ESO	69.90%	76.47%	68.42%	54.54%	56.52%	76.47%	65.00%	54.54%
2ESO	75.00%	37.50%	50.00%		00.00%	00.00%	00.00%	
3ESO	0.00%	0.00%	0.00%		0.00%	0.00%	0.00%	
4ESO	25.00%	28.57%	26.67%		50.000%	33.33%	40.00%	

Table 9. Most important extracted rules from the classification trees of Fig. 3.

	Pre-phase	Acc.	Data impact
(A)	$\{fc2 \prec 4\} \rightarrow$ 1ESO	68%	32%
(B)	$\{fc4 \prec 1\} \rightarrow \{ferc2 \prec 1\} \rightarrow \{fc2 < 10\} \rightarrow$ 1ESO	62%	13%
(C)	$\{10 \succ fc2 \succ 4\} \rightarrow \{fc4 \prec 1\} \rightarrow \{ferc2 \succeq 1\} \rightarrow$ 2ESO	48%	23%
	Post-phase	Acc.	Data impact
(D)	$\{fc2 \prec 7\} \rightarrow$ 1ESO	60%	36%
(E)	$\{7 \preceq fc2 \prec 10\} \rightarrow$ 1ESO	57%	7%
(F)	$\{16 \succeq fc2 \succeq 10\} \rightarrow$ 4ESO	58%	19%

Moreover, the smaller skew and difference between the upper and lower quartiles of the *c2* Box-Plot in the "post" phase of the TB tool Fig. 2(b), reveals a strong distribution of the values around higher frequency values as compared to the situation in the "pre" phase of the TB tool use Fig. 2(a) It is noteworthy, that other tenses that were not expected e.g. *c1* in Fig. 2(a) were also diminished in the "post" phase of the TB tool use, denoting that the students reformulated their text in the past tense. This correction trend can be noticed throughout all the four ESO levels that are presented in Fig. 2. From the errors perspective, Fig. 2 depicts decrease on *err_c2* (1st ESO) and extinction of the rest errors in all tenses (2nd-4th ESO levels) in the "post" phase of the TB tool use. Obviously, the TB tool utilization managed to support all the students towards this direction. Moreover, when examining the results across the ESO levels in the "pre" phase of the TB use (Fig. 2(a),(c),(e),(g)), an increase of the *c2* can be noticed in the essays from the novices (1st ESO) to the more experienced students (4th ESO level). Following the relevant results, in the "post" phase of the TB tool use, in Fig. 2(b),(d),(f),(h), the same trend is revealed. This finding reflects the quality of the experimental data that manage to verify an expected outcome. This preliminary analysis revealed trends in the data that were further explored through the following analysis [22].

From the building networks analysis, the problematic approach across the verb types can be realized from Table 7, as their presence is dispersed to different types than the past tense (VBD). Moreover, in the same Table it can be noticed that the VBD (verb, past tense) is of relatively low In-degree value, thus the verb of this tense was of low presence in the corpus of the errors' expressions. This means that the errors referred to other mistakes, i.e. the presence of other tenses or forms (e.g., the VB, VBP, VBG, VBZ, VBN). This initial finding along with the semantic network visualization led to further semantic analysis of the corpus of the erroneous expressions as follows.

Focusing further on to the Most Important POS Tag Patterns in the Semantic Network as they are presented in Table 7, syntactical anomalies can be detected by the interested not only concerning the verbs, but also from the broader perspective of the English sentence patterns (e.g. like NN-IN-PRP). The above analysis contributes to broader efforts of deepening to the errors of the EFL students in their essay task. In particular it manages to extract information from raw data, through algorithms, in order to reveal discrepancies between the student's performance and the expected grammatical syntax. This Micro-level information can contribute to focusing to specific learning design procedure that foresee specific emphasis to the syntactical elements of the English language.

Finally, from the building trees analysis perceptive, Fig. 3 depicts the modeling of the data in the "pre" and the "post" phase of the TB use, with Model Fit values 59.18% and 55.10%, respectively. The performance of this modeling approach is further validated in the confusion matrix, which is presented in Table 8. In this table the breakdown of errors in predictions for an unseen dataset is performed. More specifically, the accuracy of the proposed modeling is 54.54% and 54.54%, in the "pre" and "post" phase of the TB use, respectively. These values are roughly close to the relevant Model Fit values, denoting the validity of the proposed data modelling. However, as the accuracy can be sometimes misleading, additional measures are provided by the confusion matrix to evaluate the classification modelling, i.e., the precision and recall as measures of the classifiers' exactness and completeness respectively and the F-score to convey the balance between the precision and the recall. From the Table 8 it can be noticed that modelling in both the cases ("pre" and "post") are better in the case of 1st ESO level, where the most samples were provided as opposed to the 3rd ESO level (which is also missing from Fig. 3). The classification tree is a rule based approach to represent the model of interest. However, such modeling of educational data with dataset sizes similar to ours produced mixed results concerning the precision of their predictions, ranging from roughly 40% to 90%. Based on the above modelling validation findings, the proposed modelling approach can be considered satisfactory for the extraction of rules. In Table 9 the most important rules, in terms of accuracy, that are extracted from the classification trees of Fig. 3 are presented. Especially the classification in the 1st ESO level in both cases, and additionally in the 2nd ESO level in the "pre" and in the 4th ESO level in the "post" phase of the TB use is described through rules of high accuracy.

The classification trees presented in Fig. 3(a),(b) manage to reflect the TB contribution in the overall performance of the students (as depicted in Fig. 2). From a rough comparison of the trees in Fig. 3 and the rules in the Table 9, it is evident that the criteria of splitting the data from the root ($fc2$ performance) to the leaves (ESO levels) do not include the errors in the "post" phase of the TB use, as they are diminished. Moreover, the most important rules that are retrieved from this modelling and presented in Table 9, reflect the elevation of the student performance in the "post" phase of the TB use within the same ESO level. In particular, the upper range of the $fc2$ in 1st ESO level is expanded from 4 to 10 and the lower from zero to 5 as it can be drawn from the rules A and E with high accuracy.

The classification trees can be used as predictors of the depict the modelling of the students' performance, in our case, in terms of the frequency of verb uses and errors (input), from each ESO level (output), in the "pre" and the "post" phase of the TB use, respectively. Upon such Data-Driven modelling, effective predictions can be made as far as the potentiality of a student performance to be classified in a specific ESO level, when the latter is unknown.

The predictive character of the proposed modelling can contribute to early warnings on failures or prediction of success, thus it can highly contribute to findings that would be hard to be obtained through experimental methods e.g. randomized controlled trials. Predicted risks can show the likelihood of a student with certain performance on the English language to be in wrong ESO level thus receiving different teaching content and style. This information can trigger remedy actions from the interested teacher/school in early stages. Moreover, the rule based character of the proposed modelling provides a more understandable representation of the information that is hidden in the experimental data, as compared to other "black box" approaches. As such it can be easily perceived and shared among the interested stakeholders.

From the aforementioned discussion it is evident that RQ1 is answered positively as in all the experimental results such a trend has been recorded. As far as the RQ2 is concerned, this work explored machine learning analysis of the educational data that are collected by the TB and revealed hidden knowledge to them that can be used to inform the learning design towards a more refined and individual support to the student. Future extensions of the presented work include other verb tenses e.g.: continuous, extended uses of the TB and further explorations of machine learning algorithms potentialities upon the TB provided educational data.

5 Conclusions

Verb tense errors in students' free writing are common at the A1–B2 level and this study shows how English language learners can correct verb tense errors in their free writing with the help of TB. The use of this software also enhances the linguistic knowledge of the learner by providing brief metalinguistic explanations on their errors, and helps English language learners to be more cautious towards the use of the verb tenses in their writing. The use of TB allows Self-correction as it calls students' attention on the verb forms so that it is the student who decides if the verb tense is correct or not. The use of TB clearly implies an active involvement of the student in the learning process through the correction of their essays and will always be more positive than an approach in which the teacher is the one who corrects students' errors in their compositions, often leading to more work for the teacher outside the classroom and sometimes reducing the number of chances for students to practice their writing skills. This empirical study had clear pedagogic benefits for the students that took part in it. They became aware of the mistakes they made in verb tenses and they were given specific feedback that helped them to Self-correct those mistakes. Further research should focus on developing a larger database of verb tense errors and should also test the use of TB with larger groups of students, with different proficiency levels and in other teaching and learning contexts.

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Project-Based Learning Methodology for Robotics Education

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Abstract. This paper describes a project-based learning example used to promote academic success on electrical engineering, BSc and MSc degrees. The project aims to implement an aerial drone devoted to environmental surveillance, through identification and prevention of forest fires, effects of floods, and industrial flammable gases leaks to the atmosphere using an extensive set of gas sensors. The project was carried out using a hexacopter drone platform and combines knowledge of different areas, namely electronics, communications, and instrumentation. The wireless transmission of the acquired data is the main focus of the project. The results obtained from this project-based learning educational experience show that a practical-learning approach usage in conjunction with highly motivating topics promotes academic success and improves the understanding of theoretical concepts. Students increased their knowledge and skills during the problem resolution, and achieved a real solution according to their options. Moreover, this approach provides students an extensive learning experience on current technologies, modules and programming languages.

Keywords: Project-based learning · Education · Robotics

1 Introduction

During the last three decades there was an expressive increase in the number of students in higher education degrees in Portugal. That increase was due to the college network expansion with the corresponding increase in numerus clausus. Analyzing data relative to the year 2012 it is noticeable that only 28% of the resident population in Portugal, with ages comprised between 25 and 34 has completed a college degree,

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number that compares with the 39% observed on average in Organization for Economic Co-operation and Development (OECD) countries [1].

The formative efficiency in the Portuguese higher education system is also low, only 65% of enrolled students conclude their bachelors or equivalent degrees, International Standard Classification of EDucation (ISCED 6), while 71% of enrolled students complete their master's degrees, ISCED 7 [2]. These numbers are similar to those of the rest of the OECD countries in spite of the different methodological basis for obtaining them. These numbers, however, don't show a negative reality which is the high number of school-years that students take to complete their higher education degrees. Moreover, in Portugal the formative efficiency is lower in such areas as informatics, engineering, and sciences, when compared with other areas such as health, social and economic sciences, agriculture and others [1].

Several studies [3, 4] point to high percentages of dropout and failure in engineering studies due to: (a) the complexity and abstraction of the topics covered; (b) the levels of demand imposed by the professors; (c) some gaps in the students' previously acquired academic skills. Those negative numbers of dropout and failure are especially noticeable in electrical engineering. To overcome this scenario, we think a change of teaching methodologies and knowledge transmission is needed. Thus, future teaching methods in engineering must comprehend a strong experimental component in order to allow the students to acquire a set of skills, namely, design, implementation, and testing of innovative technological solutions.

The experimental validation of theoretical concepts is highly relevant to increase the motivation of students when confronted with a complex issue, thus helping them developing both elementary and incremental models of various problems.

The Project Based Learning (PBL) proposed by Barrows in [5] meets some of the predicates of the above-mentioned paradigm change and is a dynamic method that inspires students in achieving deep, integrated and profound knowledge of the topics taught by means of projects that aim to solve real-world problems [5–10]. According to the students themselves, the contents of the base curricular units lack objectivity and relevance in view of the formative objectives and induce them to boredom and demotivation, making these units the ideal candidates to the application of PBL.

Through PBL, students build a broader base of knowledge and skills while developing innovative solutions that stimulate in them the will to learn by exploring different possible paths. Those solutions that are discussed amongst a group of students with different backgrounds while the professor acts as a moderator and a tutor of the existing teams, possibly even interdisciplinary ones. When compared with the traditional teaching model, this one reinforces various soft skills such as: teamwork, argumentation, leadership, and autonomous learning that will be fundamental throughout one's professional and personal life.

The paper is organized as follows. Section 2, describes the PBL methodology implemented on the wireless communication unit. Section 3, presents the background technical concepts that the students known, related with hexacopter platforms and wireless technologies. Section 4 presents the wireless communication solution, designed and implemented by students including the platform instrumentation with different gas sensors. Finally, Sect. 5 presents the main conclusions and future work.

2 PBL Experience

The Coimbra Institute of Engineering (ISEC) is a Portuguese higher education Polytechnic school, integrated in the Coimbra Polytechnic Institute. Its formative offer includes, among others, the electrical engineering degrees, first and second cycles whose curricula have been designed accordingly to the Bologna process.

The PBL experience presented in this paper has been carried out on the Wireless Communication curricular unit of the second cycle of the Electrical Engineering course. This curricular unit aims to provide training on radio technologies on the following sub-areas: mobile cellular systems, wireless data networks and satellite navigation systems. Students who successfully complete this course should be able to: develop communications applications over mobile networks and wireless networks, install and configure modems, transceivers and Global Positioning System (GPS) receivers. Furthermore, it is intended to give students a global overview of wireless systems to allow them, in the future, the selection of the most appropriate technical solutions that meet the employers' requirements.

Each year, the unit professor presents a set of innovative projects that aim to create suitable prototypes to solve real problems, using the concepts and technologies presented during the semester. During last school-year, (2016/17), it was proposed to the students the implementation of a bidirectional radio communication using an existent wireless communication standard to control and monitor an aerial drone that collects several environmental data.

The project and its requirements were only presented in the middle of the semester to avoid students' disturbance on a topic that they don't fully master and that for which they have no critical thinking.

The class students are then divided into groups of two or three. The formation of each group is left to the students based on the knowledge of each other's skills, interests, and time availability.

The problem-based learning model used in this paper, follows the described in [12], summarizes the steps that students take to solve a problem under PBL methodology. The desired problem scenario is presented and the students perform the following steps:

- List what is known about the problem;
- Develop and analyze the problem statement;
- List out possible solutions to the problem and then select the best one;
- List actions to be taken with a timeline to complete the assignment;
- List the new topics that must be researched in order to support the solution;
- Write the problem solution, including the supporting documents in a portfolio.

Students are invited to list the technical background concepts that they have knowledge in order to solve the presented problem, or part of the problem, and prepare a portfolio that includes a presentation and a report about the obtained solution and results. The collection of the most relevant papers, surveys, book chapters and other types of information is always the first assignment/step and the starting point for the final portfolio conception. This approach places responsibility on the students and involves a considerable amount of choices regarding both: the candidate's wireless technology that best suites the problem's requirements and, on the material collected during that selection process.

Thereafter, students list the actions to be taken in the project implementation using the provided devices, transceivers and modems. For this particular project it was necessary to design a new shield that connects the microcontroller with the Radio Frequency (RF) transceiver. Students have thereafter installed an open source Arduino library to access the radio transceiver's functions in order to create and configure the wireless network that meets the project requirements. The final steps of the project are the prototype test, the collection of the most relevant results and the portfolio creation. The students communicate their solution, findings and recommendations, orally and writing, using a portfolio that should include the designed prototypes, testing results, and the proposed circuits and diagrams including Computer-Aided Design (CAD) sketches, besides the initial goals and product specifications.

At the end of the semester students have one final written exam and present the project prototype with the portfolio. The final grade of the curricular unit comprises the formal evaluation exam (70%) and the implemented project and portfolio (30%).

3 Technical Background Concepts

The problem to be solved by the students comprise the usage of an aerial drone to perform the earlier identification of natural catastrophes such as forest fires and floods and also their effects by means of a vision system in conjunction with an array of sensors with the objective of minimizing their negative effects. With an additional set of sensors, the platform may also be used to identify harmful gas leakages in industrial facilities. An aerial drone was selected, namely a hexarotor drone, bearing in mind that our institution already possessed one such platform for support of projects of this kind.

3.1 Hexacopter Platform

The system presented in Fig. 1 considers the structure of the actual hexarotor, whose arms are distributed with 60º angles between themselves and possess in their extremities electric motors with propellers directly mounted that generate both vertical and horizontal forces. These motors and propellers generate the forces that originate the aircraft's movements while in flight.

Students know that the hexacopter position control is achieved by means of the electrical motors velocity control. Each set electric motor/propeller will produce an upward force while thrusting the air downwards [11–14]. Since those generated forces are not aligned with the center of gravity, a differential force can be generated to rotate the hexarotor aircraft.

The four basic movements are altitude, roll, pitch and yaw and are considered the virtual control signals that allow the control of the propeller's velocity. The velocity of each one of them is the added contribution of these four signals. The linear movement along the earth is achieved by controlling the roll and pitch angles thus creating an acceleration that allows both forward and backward movements. The main control of

Fig. 1. Hexacopter platform.

the hexarotor is the altitude of the body in the vertical position, being a part of this signal used to compensate the effects of gravity.

The roll command is used to rotate the hexarotor while it moves forward, allowing the aircraft to move towards the right and the left by increasing or decreasing the roll signal. The pitch command is used to rotate the craft in relation to the right axis. The yaw command rotates the craft relative to the vertical axis. Figure 2 shows the applied forces to the hexarotor.

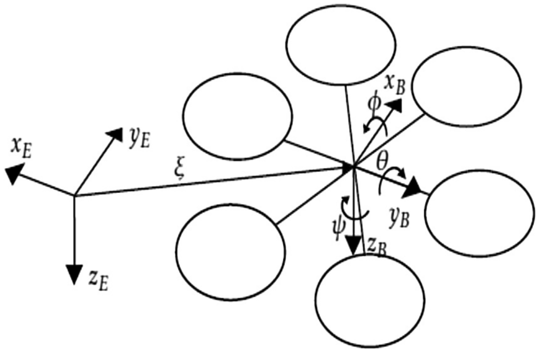

Fig. 2. Roll, yaw and pitch axis orientation, adapted from [15].

We considered this type of platform to motivate the students to integrate different technologies and acquire knowledge about wireless communications principals.

3.2 Wireless Communication

The main goal of the project was to implement a digital wireless transmission between two units according with an existent standard. In the planned solution the data acquired by the installed sensors and the images stored on the SD card, both located on the drone, are transferred to a ground station unit.

Agreeing with the presented educational design structured by steps, students should select the wireless technology capable of fulfilling the problem's requirements: moderate low data rate ($\sim$200 kbps); high autonomy, extremely low latency (<100 ms) at low cost. Among the current cellular technologies: GPRS, UMTS and LTE and wireless networks WLANs (IEEE 802.11), Bluetooth (IEEE 802.15.1), Zigbee (IEEE 802.15.4), LoRa, students have selected the IEEE 802.15.4 system. IEEE 802.15.4 is a standard that specifies the PHY and MAC for low rate Wireless Personal Area Network (WPAN) for small range usage [16].

This system is currently extensively used on home automation, automatic meter reading applications, personal health care systems, and agricultural and environmental monitoring solutions. The IEEE 802.15.4 standard main characteristics are:

- Over-the-air data rates of 851 kbps, 250 kbps, 100 kbps, 40 kbps, and 20 kbps;
- Star or peer-to-peer operation;
- Allocated short 16 bit or extended 64 bit addresses;
- Optional allocation of Guaranteed Time Slots;
- CSMA/CA or ALOHA channel access mechanisms;
- Fully acknowledged protocol for transfer reliability;
- Low power consumption;
- Energy Detection (ED);
- Link Quality Indication (LQI);
- 16 channels in the 2.4 GHz band, 10 channels in the 915 MHz band, 1 channel in the 868 MHz band.

ZigBee, WirelessHART and MiWi are high level layers, built on top of the IEEE 802.15.4, to further improve the standard according to the application domain. ZigBee is the most common specification based on the IEEE 802.15.4, enhancing the standard by adding network and security layers and an application framework. ZigBee includes two layers of the OSI model, the Application Layer (APL) and the Network Layer (NWL) that operate on top of the protocol PHY and MAC layers.

As mentioned, the standard provides high throughput and extremely low latency, making it suitable for real time applications. It implements a fully reliable "hand-shake" protocol and three possible network topologies: star, mesh and cluster-tree; allowing up to 65535 network devices supported by an up to 64 bit IEEE address.

There are three types of devices in a ZigBee network: a coordinator, single device on the network, which creates and configures the network, acts as the coordinator of the IEEE 802.15.4. However, once the network is formed it is a Full Functional Device (FFD) that implements the full protocol stack and makes the interconnection between other networks. A router that is also an FFD, will forward the packets on the network, relaying data. Finally, a ZigBee end node that can only transmit data packets to the network without additional functionality and does not participate in routing. ZigBee end devices are Reduced Function Device (RFD) that implements a reduced subset of the protocol stack, as a result low energy consumption is observed for low duty cycle working modes.

3.3 MRF24J40 Transceiver Module

Students have compared some IEEE 802.15.4 compliant RF modules available in the market according with the energy consumption and the radio propagation range of each module. The MRF24J40 transceiver from Microchip was the selected one, however despite the variety of Microchip PIC microcontrollers, students decided to use the ARDUINO UNO microcontroller development board to implement the proposed project.

The MRF24J40MA is an IEEE 802.15.4 compliant radio transceiver module that operates at the 2.4 GHz ISM band. The mentioned transceiver has an integrated PCB antenna, matching circuitry, and supports the protocols: ZigBee, MiWi, MiWi P2P and proprietary wireless networking protocols.

The protocol implementation code is stacked on the external microcontroller flash memory. Due to memory limitation is common to use the MiWi and MiWi P2P, two simplified protocols based on IEEE 802.15.4 with light upper layer stack instead of the ZigBee. The MRF24J40MA module connects to an external microcontroller, in our case an ARDUINO UNO, via a 4-wire Serial Peripheral Interface, SPI interface, namely SDI (MOSI), SDO (MISO), SCK (Clock) e CS (Chip Select).

The transceiver presents low-current consumption: 23 mA @ TX mode; 19 mA @ TX mode and 2 μA Sleep mode; two different data rates 250 kbps (IEEE 802.15.4 compliant) and 625 kbps (Turbo mode).

The module typical sensitivity is −95 dBm allowing outdoor propagation range up to 80 m if PCB antennas are considered.

The Media Access Controller (MAC) circuitry verifies reception and formats for transmission IEEE 802.15.4 standard compliant packets, providing hardware support for: Carrier-Sense Multiple Access with Collision Avoidance (CSMA-CA) mechanism; automatic packet retransmission; automatic acknowledgement response and FCS check. Data is buffered in Transmit and Receive FIFOs. These features reduce the processing load, allowing the use of low cost 8 bit microcontrollers [16].

4 Final Solution Proposed by the Students

Students have designed a printed circuit board (PCB), presented in Fig. 3, to connect the MRF24J40 chip with the microcontroller; the PCB includes other components and sockets. The shield was designed using the EAGLE software, and was based on the schematic of the chip datasheet.

Control registers provide control, status and device addressing for MRF24J40 operations. In addition, FIFO serve as temporary buffers for data transmission, reception [17]. The SPI communication with the MRF24J40 module reads and/or writes data in those registers and FIFOs. The first byte is the desired register address the following byte corresponds to the data that should be read or write from/to that particular address.

Table 1 summarizes the control Registers used during the IEEE 802.15.4 point-to-point (P2P) communication, specifying their functions and its most relevant bits.

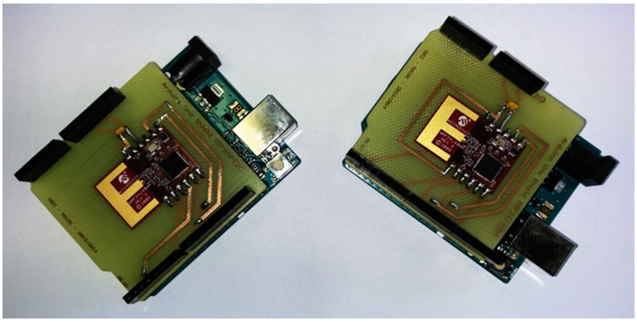

Fig. 3. Developed shield based on the MRF24J40MA.

Table 1. Control registers used in the program.

Address	Name	Register bits functions
0x1B	TXNCON	Transmit the frame in the TX Normal FIFO (bit 0) and perform an Acknowledgement Request (bit 2)
0x32	INTCON	TX Normal FIFO Transmission Interrupt Enable bit (bit 0) and RX FIFO Reception Interrupt Enable bit (bit 3)
0x36	BBREG0	RF State Machine Reset bit (bit 2)
0x38	BBREG0	Turbo Mode Enable bit: 1 = Turbo mode (625 kbps), 0 = IEEE 802.15.4™ mode (250 kbps)
0x200	RFCON0	Channel Number definition (bit 7-4), e.g. 0000 = channel 11 (2405 MHz)
0x201	RFCON1	VCO Optimize Control (bit 7-0), Recommended value: 0x1
0x202	RFCON2	bit 7 must be enabled for RF RX or TX
0x206	RFCON6	bit 7 enabled TX Filter Control bit

4.1 A. Microcontroller Programming

The microcontroller was programmed, by students, in C++ using the available IDE. The extensive usage of this open source electronic platform by students; hobbyists and engineers promoted a community very active in forums and blogs sharing and reading tutorials, tips and libraries dedicated to this platform. As already stated the drone has a camera with an accessible SD card, being one of the aims of this project the files transfer to the ground station. Thus, students have selected the "SD Library" to read the SD card files and the library developed by Karl Palsson to configure and use the MRF24J40MA transceiver in a point to point communication.

Under initial tests, students have observed significant data losses in the received information, during a JPEG file transfer. In order to mitigate this problem, a detailed set of tests has been carried out in both the developed hardware shield and in the software, including the installed libraries. The implemented hardware shield was extensively tested and works properly.

After some tests, running some basic data transfer functions, an error was identified in the buffered data extraction process. The original version of the code presented in the library, extracts all the fields of a particular data frame including the MHR 9 bytes and the MFR 2 bytes. The data payload info was thereafter removed and verified. Students have proposed new code that performs the desired task without problems. Some other parameters have been modified, namely the channel that supports the communication.

Besides the data values, the designed protocol includes in the first byte additional information regarding the task that is performed. During a file transfer procedure, the value 0x01 indicates that a new file transfer will start; the value 0x02 point out that the transferred data is part of a file that is under a download process and finally the 0x03 value means that the data in the transmitted packet belongs to the last part of the file, in our case a JPEG file. Header values in the range 0x06 to 0x08 specify that the data correspond to one particular gas sensor.

4.2 Platform Instrumentation

Gases can be classified in three distinct groups: flammable; inert gases and oxidizers. Flammable gases are those that can explode or burn (combustion reaction) when combined with an oxidizing gas (namely air or oxygen) in the presence of an ignition source. Inert gases do not take part in combustion processes neither react with other materials.

Oxidizers are not flammable however they foster the combustion as an oxidant. The most common examples of flammable gases include: butane (C4H10), propane (C3H8), hydrogen (H2), methane (CH4), carbon monoxide (CO), etc. Taken into account that one of the goals of the proposed prototype was the detection of molecules of different flammable gases and smoke, as efficiently as possible, students have decided to select low cost semiconductor sensors with high sensitivity values to those particular gases.

MQ-2 gas sensor has a high sensitivity to propane and smoke; also, can detect the natural gas and other flammable steam well. MQ-4 gas sensor has high sensitivity to methane. MQ-6 gas sensor detects a variety of flammable gases such as iso-butane and propane; it has high sensitivity to Liquefied Petroleum Gas (LPG).

Finally, MQ-7 sensor is used to detect carbon monoxide (CO). All the sensors used are characterized by having a quick response and a long-life time and stable. MQ4 and MQ6 sensors will provide real time information on the level of concentration of the flammable gas to the microcontroller.

Figure 4 presents the hexacopter drone in operation, transmitting the acquired data to the ground station using the developed wireless communication solution based on the IEEE 802.15.4 protocol.

Fig. 4. Hexacopter drone operation.

5 Conclusions and Future Work

This paper presents an educative experience conducted in some units of the electrical engineering course, taught in the Coimbra Institute of Engineering. In those units the PBL methodology was used to increase motivation, to improve learning outcomes and to promote autonomous learning and transition to real professional practice.

The proposed project aims to design and implement a drone to identify some natural catastrophes and industrial hazards, namely flammable gases leaks. The project was conducted based on an existent platform being the students responsible the development of a new software application to simulate, test and implement the drone controllers. Moreover, some other relevant aspects covering the design and implementation of communication units and the platform instrumentation were also conducted with success. During the classes, students have implemented two nodes comprising an original shield that includes the MRF24J40 transceiver connected with an ATMEL microcontroller and a SD card. The selection of those devices fulfills the problem requirements.

The PBL methodology was used in the wireless communication unit, in the last four year, being the learning outcomes results the following ones. All the enrolled students that attend more than 80% of the unit classes have succeed in the laboratorial component being the success rates of unit the following ones: 84.6% (9/11) in the 2013/14 academic year; 87.5% (14/16) in 2014/15; 81.8% (9/11) in 2015/16; and 100% (8/8) in the 2016/17.

Summarizing, the presented PBL experience based on an educational robotic platform has promoted the academic success, the students' motivation and commitment facing a complex problem and the reinforcement of some others soft skills such as teamwork and leadership.

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Using a Non-educational Mobile Game for Learning in Biology, Geography and Mathematics: Pokémon Go as a Case Study

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Abstract. ICT offers new perspectives in teaching and learning. In this paper a popular non-educational mobile game, "Pokémon Go", is used as a background for the design of educational activities in Biology, Geography and Mathematics and as a means of informal learning. Five secondary level students (14–15 years old) participated in this study. Data were collected through observation, field notes and interviews. The participants described the activities as attractive, pleasant and creative and stated that there is a lack of engaging learning and technology use in school. The results show that an effective integration of mobile technologies can enhance learning and students' attitude.

Keywords: Non-educational mobile apps · STEM · Mobile learning · Augmented reality · Game-based learning

1 Introduction

In this study activities about several subjects were designed using the 'Pokémon Go' mobile game environment. Pokémon Go is an application designed primarily for entertaining and socializing purposes, and is considered as a great example of disruptive technologies [1]. This decision of using a non- educational application brought to the fore the following reflection: commercial games are considered far more interesting and attractive than educational ones but they lack of support for the learning experiences [2]. In order to solve this questioning our study attempts to provide an educational setting, in which participants are playing and constructing knowledge through interaction with the game universe [2]. Apart from implementing the activities in a variety of subjects, effort was made to use different key features of mobile gaming which could be useful in an educational context.

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2 Theoretical Background

2.1 Mapping the Area of Mobile Learning

New possibilities and challenges in learning and pedagogy connected with changes in technology continue to appear. The notion that mobile learning (ML) is more than just integrating mobile technologies and mobile devices [3] is reinforced by El-Husein and Cronje [4] who refer to ML as 'any type of learning that takes place in learning environments and spaces that take account of the mobility of technology, mobility of learners and mobility of learning. Student engagement seems to increase when mobile technologies are incorporated in instruction, also due to their capability of intersecting learning styles [5]. The most significant factors that are considered to negatively affect learning and students' perceptions about learning are the instructional design and comfort with technology, if they are not properly arranged [5].

Tu and Sujo-Montes [3] suggest integrating mobile technologies through transforming students' mobile devices into learning devices and learning tools. This transformation is oriented to the personalized, context specific and easily mobilized features that enhance learning in innovative ways. Students have the opportunity to reach larger range of content and approach the educational process and material from anywhere, anytime [5]. This flexible, ubiquitous character of mobile devices opens the picture for mobile learning advantages. Educators play a key role in the design of activities, implementation of new technology, cultivating mobile information literacy in students and finally adapting the technology in specific learning goals and outcomes [5].

Mobile technologies, and particularly mobile games, have been used in a variety of settings, both formal and informal, in support of student learning [6]. Recently, mobile games earned a prevailing place among other gaming platforms (PC, consoles, arcade games), thanks to the mobility, networkability, accessibility and simplicity of mobile devices [6]. Although research must focus on the situated nature of game-player interactions, factors such as the instructional design and the facilitating role of the teacher should also be included.

2.2 Augmented Reality

Pokémon Go, the selected app for the study, bears an embedded AR feature. The consideration of AR as a concept rather than a certain type of technology provides opportunities for exploiting AR for educational purposes. According to Wu et al. [7] AR affordances in education could be summarized in the following: (a) learning content in 3D perspectives, (b) ubiquitous, collaborative and situated learning, (c) learners' senses of presence, immediacy, and immersion, (d) visualizing the invisible, and (e) bridging formal and informal learning. AR is a live, direct or indirect, view of a physical, real-world environment allowing mobile users augment their interaction with their surroundings by providing elements such as video, graphics or Global Positioning System (GPS) data [3].

2.3 Game-Based Learning

According to Qian and Clark [8] the term game-based learning describes an environment with two main characteristics: First, knowledge and skills are enhanced through game content and gameplay. Secondly, a sense of achievement is provided to players, through problem solving incorporated in game activities.

The explosive development and popularity of video and mobile games has directed educational research to focus on digital gaming, as a possible effective educational tool. Findings that support this assumption indicate that video games provide a learning environment which increases students' interest and motivation [9].

Motivational mechanisms used in game-based learning interventions include badges, leaderboards, points, levels and virtual goods [10]. These design principles have a great emotional and social impact on students, as reward systems and competitive social mechanisms seem to be motivating for them [11]. While analyzing the motivational effect of game-based learning, it becomes obvious that a major aspect in this context are performance goals. Mastery goals contrary, which refer to the desire to master new knowledge play a minor role.

In order for game-based learning to step to the next level meaningful implementations, not limited in extrinsic rewards should be developed [12]. Some elements which could be considered are providing players a strong sense of autonomy by giving different routes to the ultimate goal [13] and recursive play through failure [14].

2.4 About Pokémon Go

Pokémon Go is a location-based augmented reality game for Android and iOS, developed by Niantic, that incorporates the above-mentioned characteristics. It ranks as one of the most downloaded apps of all time. The player has the opportunity to find, encounter and capture small monsters (Pokémon) of the well-known Pokémon franchise in the real world. Certain places of interests, such as landmarks, parks, statues etc. serve as either gyms, where the battles take place, or PokéStops, which provide players with useful items. Almost every move in the game rewards the players with experience points (XP) that help them level-up and become more competitive. AR mode uses the camera and the gyroscope on the player's mobile device to display the Pokémon in the real world. Different species of them can be encountered in different areas. For instance, water- type Pokémon are most likely to be found near lakes or seas. Despite its massive success, there is a scarce of studies with actual use of Pokémon Go for educational purposes. In this study, Pokémon Go is used as a learning tool in the fields of Mathematics, Geography and Biology and its educational potential is investigated.

3 Research Methodology

This study aims to explore the point of intersection between mobile apps and their educational affordances when integrated into the learning process effectively. The study had the following research questions:

1. In which ways can a non- educational mobile application work as a background for designed activities that support learning?
2. What are the participants' perceptions and attitudes about such applications and the designed activities?

The convenience sample included four secondary level students, 14–15 years old, from public schools of Thessaloniki. All of them had previous experience with the game. Every student got involved in one of the three activities. Each of them lasted approximately 2 h. Data were collected through observation and field notes during the implementation and through interviews after the completion of the activities. The interviews were semi- structured and had the following three sections: student's relation with technology (school and every-day life), student's impressions and attitudes towards the game and the activities, student's views about the use of gaming applications at school. In order to achieve greater validity, each researcher undertook one activity and worked separately. The results of these three sources were then compared and discussed and the final conclusions were drawn.

4 Activities

4.1 Biology

The concept of evolution is described as a delicate, complex teaching objective, particularly exposed to confrontations with the ideas belonging to the public domain and beliefs influenced by cultural factors [15]. However, due to its prodigious ability to enable people make sense of the natural world, a proper understanding of evolutionary theory is a critical aspect of scientific literacy [16]. In the same direction lies the need for providing chances for scientific skills development in the teaching of science subjects is highly supported by [17]. The designed activities aim to support biology content but also its facet as a scientific process. The game's universe works ideally as a basis for practicing inquiry skills such as identifying common characteristics and exploring how these characteristics affect and being affected by environmental factors.

In the first series of activities the two participants organized their catching activity in lists and discussed their ideas about making categories out of this number of collected Pokémon based on a criterion (e.g. size, type, level, class). Then, they were asked to identify similarities between different groups of Pokémon and differences between Pokémon that they have placed in the same category. Observation and classification, as well as the decisions taken in the game's context were at the heart of the activity. In the second series of activities students were asked to describe external characteristics of Pokémon and link specific characteristics with the natural habitat of the organisms. Students had the opportunity to collect information about Pokémon characteristics in order to identify which of these are based in real life organisms. In this way students are triggered to explain how these features provide organisms the collateral of their survival, such as natural ways of protecting themselves, helping them collect their food etc.

The context of the activities, the mobile app environment, is closely related with students' interests and experiences and framed by historical information about Darwin's work. Learning goals referring to knowledge background and scientific processes (such as observation) function as motivating structures and can be used as a basis for further cognitive and skill development. It must be mentioned that the understanding of those rather challenging concepts such as natural selection is far from the proposed activities' impact.

4.2 Geography

Urban landscapes and the historical-cultural context of their landmarks, provide a perfect field for students to exercise their orientation and map-reading skills. The Pokémon Go interface provides a very usable digital map that is enriched with features that underline important landmarks of the city like Pokéstops. Apart from that, Pokémon Go provides a rich arsenal of gaming mechanics that include reward systems like the collection of experience points through a variety of actions (Fig. 1).

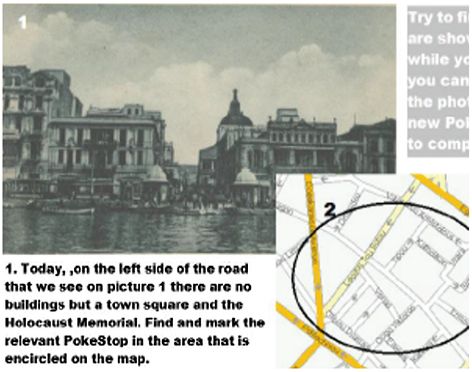

Fig. 1. Part of the worksheet used for the geography activity.

During the activity the student searches for certain places or buildings of Thessaloniki while playing Pokémon Go and taking directions by a worksheet. On the worksheet the spots they have to find are shown through old photos. Text hints provide information and guidance and encircled areas in a modern Thessaloniki map indicate where they have to search each spot, which are Pokéstops. Apart from the Pokéstops, another feature of the game that is used is that students have to collect as many different Pokémon they can. For every one of the spots they find and mark correctly on the map, the students gain 30 points and for every different Pokémon they gain 1 point.

4.3 Mathematics

Problem Solving is among the most important concepts in school Mathematics. A mathematical problem should be attractive, comprehensible, interesting due its intriguing context and allow students to apply their knowledge and skills in authentic, non-routine problem situations [18]. There are 3 types of quantitative estimation skill: numerosity, computational and measurement estimation [19]. The following problem is related to the last type, on which very few researchers and teachers have focused [20].

Thanks to the AR feature, one can take photos of the Pokémon in the real world, before trying to capture them. In this activity the participant was asked to take such photos and then to estimate the height of each Pokémon by comparing it with objects of the real world in its environment, whose size was known (e.g. about 2/3 the height of the bench, about 1/4 the height of the fountain). The sizes of the real objects were measured (e.g. bottle) or retrieved from the web (e.g. statues). Even based on accurate numbers, the final estimation could not be absolutely accurate, so the student was also free to estimate a size (e.g. tree) or round it up. The game provides information about the "real" height of each Pokémon, and the student could compare it with her estimation. The student was asked to interpret the comparison using the following calculations: the difference between the estimation and the exact height ($|a - e|$), the fraction a/e (Approximate Value/Exact Value) and the respective percentage ($a/e \times 100\%$), the percentage error: ($|a - e|/e) \times 100\%$. A table with these data was then constructed for each picture. For example, in the following photo taken by the student (Fig. 2) "Marowak" seems to be about the height of the car (approximately 1.8 m). However, according to the game it is 1 m tall. So for this Pokémon:

- $(|a - e|) = 0.8$
- $a/e = 1.8$
- $a/e \times 100\% = 180\%$
- $(|a - e|/e) \times 100\% = 44.44\%$

Fig. 2. An AR photo example for the mathematics activity.

5 Results and Discussion

According to the observation, the designed activities based on the game were proven to be very engaging for the students and thus they are considered to be successful. The biology activities attempted to integrate scientific processes with content and context related to the concept of evolution, which is considered rather exigent. The designed problem solving activity in mathematics helped participants comprehend and practice measurement estimation, a concept seldom taught in classroom, in a joyful way. The geography activity evoked participants' active engagement with demanding orientation and map reading activities, while leading them to discovering unknown until then city spots. Examining the results of the analysis in a comparative way indications about the designed material and the whole experience lie in similar and complementary directions for each of the subject area.

More specifically, all participants were proven to be frequent users of technology, mainly smartphones and tablets, in their everyday life. On the contrary, technology is absent from their school subjects, except for the ICT lesson.

The effective integration of mobile technologies allowed students interact not only with content but also with information related to the environment these ideas were developed. Activities were described as attractive, pleasant and creative. All the interviewees were either positive or enthusiastic about the implementation of such activities in school. For example, two students said:

> *"School activities are never so pleasant. In this activity I had to do things on my own and not just solve a given task"*

> *"The most interesting part was that I saw an app I use every day from a different perspective."*

They believe that the main reasons this does not happen are the lack of time, the fact that many teachers do not care or do not know how to make their subject more interesting and the learning more pleasant. For instance, one student stated:

> *"It does not happen because most teachers don't know how to do it. Some of them may just avoid it, since such things need time. I am sure I would be more interested in the lessons and appreciate the teacher that devoted time to devise such a lesson and risk to go beyond the textbook and usual way of teaching."*

6 Conclusions

In this paper the design, implementation and analysis of an informal learning setting using Pokémon Go as a non-educational mobile app was presented. Findings indicate that the designed material actively engaged participants, providing them with experience-based learning opportunities. The area of interest consisted of various subjects (mathematics, geography and biology). Each of the implementations was designed in order to support the nature and the content of the subject utilizing effectively the affordances of the mobile app environment (e.g. augmented reality features were used for informal estimations of height in the mathematics activity). The limitations of this study, such as focusing only in one mobile application, a short research period and a restricted number of participants, point in future research possibilities. One of the emerging 'quests' could be gaining deeper understanding of perceptions about the educational system and its impact to students' lives. Realizing instructors' role in learning is just one of the crucial elements. So, what are their proposals in bridging their out-of-school ICT experiences with learning inside school? Maybe this and other questions function as guidelines in upcoming research work. Finally, mobile apps open the picture for new opportunities in teaching and learning. An ensemble of factors that extend from the learners and teachers role should be carefully considered in order to constitute a concrete setting for applying reforming pedagogical strategies and effectively integrating mobile technologies in learning.

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Towards an Intelligent Learning Management System: The A/B/C-TEACH Approach

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Abstract. The new dimensions of e-community and e-identity have justified the integration of innovative methodologies in the design, implementation and development of the teaching-learning process at Higher Education Institutions (HEIs). The growing adoption of Learning Management Systems (LMSs) has led to the introduction of creative teaching/learning approaches and to the promotion of different educational contexts within the online environment. From this perspective, the A/B/C-TEACH project (http://abcteach.fmh.ulisboa.pt/) is presented here, exploring the ways effective teaching could be accomplished when bridging the fields of affective (a)-, blended (b)- and collaborative (c)-learning into a hybrid, LMS-based, enhanced teaching-learning environment. New guidelines about the enhancement of LMS-based teaching/learning processes are presented, contributing to the enrichment of the HEI services and re-examination of educational policies/practices.

Keywords: Learning Management Systems · Affective-learning · Blended-learning · Collaborative-learning · A/B/C-TEACH

1 Introduction

Enhanced teaching involves new ways of educational processes that include face-to-face (F2F) and online modalities, realizing the concept of blended (b-) learning. Moreover, collaboration is a central cornerstone in the teaching/learning process, fostering interaction and co-participation/creation, along with knowledge building and social skills enhancement. Apart from the cognitive factor, however, equally important is the affective one, as emotional loadings could drive and affect interactions during the educational process. So far, conventional teaching usually adopts the concepts of affective (a-), blended (b-), and collaborative (c-) learning as independent learning

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pathways, neglecting the important interconnections and benefits that could be provided to both educators/learners, when considering them as educational activities of a common educational scaffold. In addition, Learning Management Systems (LMSs) like Moodle, despite their proliferation, are commonly used as educational material repositories, solely providing some basic analytics that are not integrated as constructive feedback within the educational process. A/B/C-TEACH (http://abcteach.fmh.ulisboa.pt/) attempts to renovate this status by proposing a holistic educational approach, which integrates a-/b-/c-learning within an intelligent LMS (iLMS) environment, by providing tangible, dynamic and personalized indices, i.e., quality of interaction (QoI), quality of collaboration (QoC) and affective state (AS) of the LMS users, as novel tools for rethinking the way knowledge is delivered.

From this perspective, an enhanced environment-based intelligent teaching/learning modeling approach is foreseen in the present work, by incorporating innovative processing techniques from the Fuzzy Logic (FL) field and affective computing. The A/B/C-TEACH framework adopts a holistic approach of the fundamental channels from which the educational process is conveyed, combining cognitive, affective and social information of the peers' behavior and interactions. In fact, the findings of the latter would increase the scientific awareness of the intelligent environments and help managers/designers to provide a fast and early feedback to the Higher Education Institutions (HEIs), to enhance their level of online learning environments (OLEs) efficiency.

1.1 Bridging Affective, Blended and Collaborative Potentialities

In the last decade, there has been an accelerated flow of findings in multiple disciplines, supporting a view of affect as complexly intertwined with cognition in guiding rational behavior, memory retrieval, decision-making, and creativity, progressively boosting the role of a-learning to the foreground [1]. Additionally, the combination of traditional Face-to-Face (F2F) and online learning initiated the concept of b-learning, combining different delivery methodologies/modes that have the potential to optimize the learning development, deployment costs and time [2]. In parallel, education paradigms shifted to incorporate online c-learning environments, assisting students to feel more interactive and also exert a positive influence in terms of motivation, behavior and self-determination, as well as engagement in learning activities [3, 4].

Considering the abovementioned, a research framework is presented here, which explores the ways effective teaching could be accomplished when bridging the fields of a-, b- and c-learning into a hybrid system-based, enhanced teaching-learning environment. In addition, in order to enhance the online educational process towards effective teaching, the following research questions could serve as a general guide: (i) Can the quality of interaction (QoI), quality of collaboration (QoC) and affective state (AS) of the OLE users contribute to the efficiency of the a-/b-/c-learning methodologies? and (ii) How the educational practices at HEIs could be improved, using a-/b-/c- teaching-learning potentialities?

1.2 Fuzzy Inference Systems (FISs) in Educational Contexts

A Fuzzy Inference System (FIS) can be seen as a method where a multiple-input model can be constructed in an easy way. One of the key aspects of its success is the ability to incorporate human/expert knowledge where information is described by vague and imprecise statements. Moreover, the behavior of a FIS is expressed in a language that is easily interpreted by humans. In addition, FIS has demonstrated its ability in a variety of domains, e.g., control, modeling, and classification issues [5].

Focusing at the educational content, a variety of research works has used the concepts of FL and FIS. These spans from initial approaches in '90s [e.g., 6–9] to a more extended depth after 2000, [e.g., 10–15]. After 2010 a connection of FL with the data from LMS was attempted with the pioneering work of Dias and Diniz [16], who have introduced the FuzzyQoI model that, by employing FL constructs, it quantitatively estimated the users' QoI with the LMS Moodle within a blended-learning environment. They considered a set of 110 LMS Moodle metrics to form 12 codified inputs to a five-level FIS equipped with 600 expert's fuzzy rules. Moreover, the findings revealed that the proposed FuzzyQoI model efficiently identified (dis)similarities in LMS interaction trends, correlations, distributions and dependencies with the time-period of the LMS use [16, 17].

In parallel, the use of Adaptive Networked-based FIS or Adaptive Neuro-FIS (ANFIS) in education contexts has been explored. Neuro-fuzzy inference systems (NFIS) are fuzzy systems, which adopt artificial neural networks (ANNs) theory, in order to determine their properties (fuzzy sets and fuzzy rules) by processing data samples [18]. An approach in modeling collaborative and metacognitive data, namely Collaboration/Metacognition–Adaptive Network-based Fuzzy Inference System (C/M-ANFIS) was proposed by Hadjileontiadou and Hadjileontiadis [19]. They concluded that this model can be used for efficiently modelling skills and beliefs in computer-mediated collaboration using neuro-fuzzy models and, at the same time, useful to predict the quality of collaboration during collaborative sessions. More recent ANFIS-based applications in the field of education can be found in [20–22].

Taking into account the aforementioned perspectives, the rest of the paper is constructed as follows: first, the general architecture of the A/B/C-TEACH framework is presented, followed by a description of the main modelling techniques used. Upon these, practical implications to HEIs and emerging trends about the enhancement of LMS-based teaching/learning processes are provided. Finally, conclusions and future work conclude the paper.

2 A/B/C-TEACH Architecture

Using LMS Moodle data logger, built on the pedagogical approaches of behaviorism, cognitivism, constructivism, connectivism, A/B/C-TEACH produces new metrics regarding the interaction and collaboration amongst users. A schematic representation of the A/B/C-TECH architectural structure is depicted in Fig. 1. From the latter, the dynamic flow of information between the distinct structural modules and participants is evident; more specifically, the interconnected elements of Fig. 1 include the following:

- *Users*: M teachers and N learners are coexisting and interacting both through the F2F and online learning environments under the b/c-learning concepts.
- *Data Acquisition/Management Module*: in general, OLEs easily allow the acquisition and management of user data; from this vein, a series of metrics regarding the interaction and collaboration amongst users are available. In particular, 110 LMS metrics were used (e.g., wiki, blog, forum, chat, quiz, edit), forming interaction qualities and contributed to the estimation of QoI. At the same time, collaborative interactions (e.g., proposals, contra-proposals, questions, turn-taking balance) were used for the estimation of the QoC.
- *Affective Module*: considering the data from the users' affective module, supporting a-learning, this module will avoid the typical path of evoking questionnaires to measure the learners' affective experience - such as how much pleasure, frustration, or interest they felt during the learning processes, and evaluating the motivational characteristics of an instructor's delivery. On the contrary, by using affective computing cutting-edge technology (e.g., EEG EMOTIV EPOC/INSIGHT, webcams/depth cameras, portable functional near-infrared (fNIR) spectroscopy) it would provide real-time data, related to the users' ASs.
- *Fuzziness/Hybrid Modeling*: considering the data from the previous modules, the hybrid modeling will use innovative techniques from the fields of fuzzy set theory, neuro-fuzzy modeling, fuzzy cognitive maps, dynamic nonlinear analysis, and affective computing. Moreover, by adopting Lang's emotion space combined with advanced signal processing techniques [23] emotion recognition processes of the AS data will take place.
- *Features*: the main features that will be outputted from the constructed models include users' QoI, QoC and AS (learners only).
- *Feedback*: having the aforementioned estimated features per user, the construction of personalized feedback will be fired. The latter will be focused upon initiating metacognitive processes, helping the users to become more aware of their interaction, collaboration and affect - building a kind of "interactive/collaborative/affective mirror" in which the learners are encouraged to reflect upon how their interaction/collaboration behavior and affective state are influencing their learning experience. For example, emotional awareness, in oneself and in others, is considered to be a learnable skill of emotional intelligence. Being aware of one's state, such as frustration, can be instrumental in helping deal with that state, productively. Moreover, enriched feedback regarding more global findings will be provided to the HEI's policy stakeholders towards intelligent OLE.

In general, intelligent learning environments should be able to adapt to the knowledge, emotions, learning abilities and needs/preferences of each user. A new range of expressive technologies and a more integrated methodology to facilitate rooted knowledge construction and support development of shoots to new areas through online education in the context of effective teaching at the HEIs are really needed. Considering the aforementioned perspectives, the combination of a-, b- and c-learning environments (learning systems), scaffolded by the potentialities of the FL-based modeling approaches presented in this work, can contribute to creative learning approaches, encouraging efficient OLE instruction design processes, and blending theoretical concepts with practical implementations, towards a more intelligent OLE. With the use of the latter, adaptive learning environments can be realized, offering substantial support for the instructional design process through adaptive direction and personalized online and open learning resources. In the next section, a description of the main modelling techniques used in the A/B/C-TEACH approach is provided.

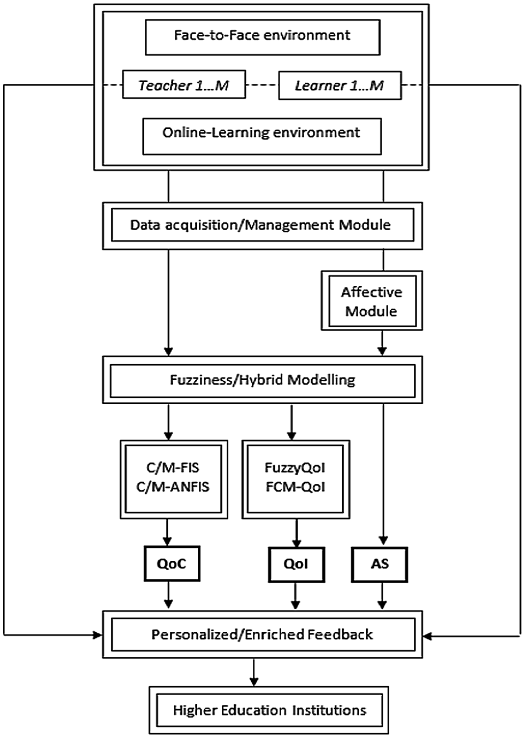

Fig. 1. Schematic flow-diagram of the A/B/C-TEACH framework towards effective teaching, by bridging affective-, blended- and collaborative-teaching and learning potentialities

3 Methodology

Initiated by the pioneer work of Zadeh [24] on fuzzy logic (FL), almost fifty years later, FL-based inference systems (FL-ISs) have become one of the most famous fields of FL. The main reason of the latter is the ability of FL to incorporate human's expert knowledge with its nuances, as well as to express the behavior of the system in an interpretable way for humans. In this way, innovative modelling/analysis techniques are used in the A/B/C-TEACH modelling module (see Sect. 2-Architecture) by incorporating hybrid and innovative processing techniques from the fields of fuzzy set theory, neuro-fuzzy modelling, dynamic nonlinear analysis, and affective computing, as depicted in Fig. 2. More specifically:

- The *Collaboration/Metacognition-Adaptive Fuzzy Model* (C/M-AFM) model is defined on the basis of the balance of the collaborative activity within the dynamic of the pair in an online learning environment, triggering collaborative and metacognitive interactions, to enhance the quality of collaboration (QoC) (Fig. 2(a)) (analytical description of the C/M-AFM model can be found in [12]).
- The *Collaboration/Metacognition-Adaptive Neuro Fuzzy Inference System* (C/M-ANFIS) model, which supports the advancement of online collaborative skills, employing a neurofuzzy structure to model the individual collaborative strategy across sessions of peers' collaboration, i.e., at the micro-level. Using this knowledge, the C/M-ANFIS estimates the value of a feedback indicator concerning the quality of the individual collaborative activity (QoC) in a forthcoming session of collaboration (Fig. 2(b)) (analytical description of the C/M-ANFIS model can be found in [17]).
- The *Fuzzy Logic-based modeling of the Quality of Interaction* (FuzzyQoI) model incorporates the LMS Moodle metrics to estimate the users' QoI using Fuzzy Logic (Fig. 2(c)) (analytical description of the FuzzyQoI model can be found in [16]).
- The *Fuzzy Cognitive Map-based modeling of the Quality of Interaction* (FCM-QoI) model, is an extension of the FuzzyQoI model, which involves concepts interconnection and causal dependencies representations of LMS users' interaction behavior to estimate the users' QoI (Fig. 2(d)) (analytical description of the FCM-QoI model can be found in [25]).
- The *emotion recognition* process using EMOTIV EPOC Headset and EEG analysis quantitatively estimates the degree of emotion elicitation in subjects under suitable stimuli and the overall enhancement of the EEG-ER systems performance by introducing new feature vectors (Fig. 2(e)) (analytical description of the this work can be found in [23]). This could be further enhanced by the sentiment analysis of the peers' LMS Moodle forum posts.

Moreover, A/B/C-TEACH already analyses the data acquired from 5200 students from 75 disciplines (80 teachers) across the period of the first 3 years (2014–2016), coming from the Faculty of Human Kinetics, University of Lisbon in Portugal and the Aristotle University of Thessaloniki in Greece. Moreover, since a collaboration with the Khalifa University of Science and Technology (KUST) of UAE, has already been established, it is anticipated soon to be embraced by the educational system of KUST, which is already designed around the everyday use of LMS Moodle. Consequently, a significant increase in the A/B/C-TEACH students ($\sim$8000–10000) is expected in the next three years of the research (2017–2019).

In the succeeding section, practical and managerial implications for educational contexts, along with the contributions of each model are presented.

4 Practical Implication to HEIs

Comprehension of the potentialities of the proposed fuzzy logic-based modeling approaches explored in the previous section (Sect. 3-Methodology) and the way they could be transferred to tackle real problems in the educational context, contributes to the establishment of a learning ecology for reflection and rethinking upon the intelligence of the online learning environments as current and future constructs. Succeeding subsections show the contribution and functionality of each model to the educational settings by providing tangible, dynamic and personalized indices (e.g., QoI and QoC).

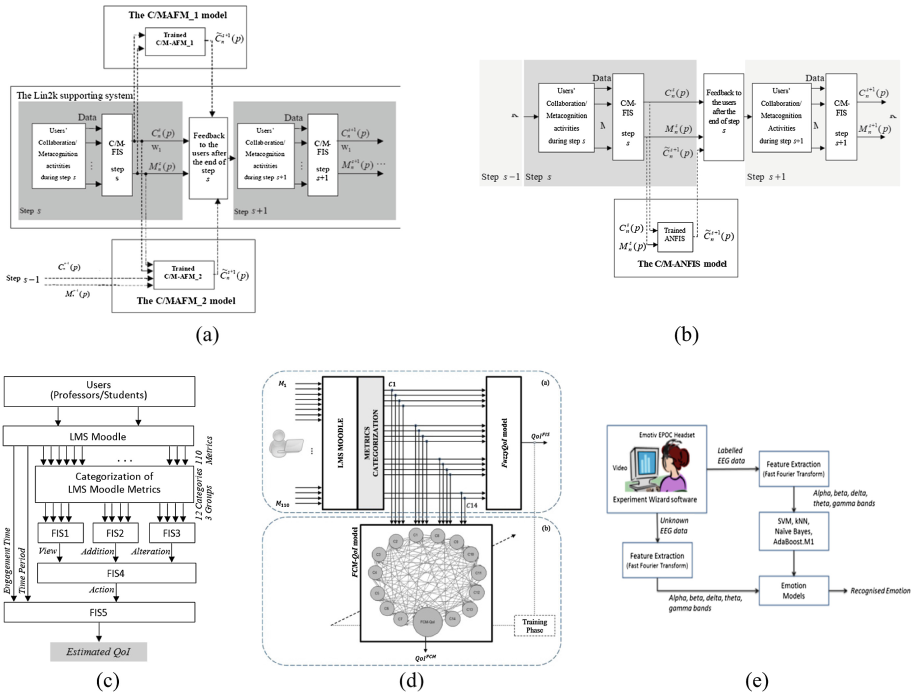

Fig. 2. Examples of innovative modelling/analysis techniques that are incorporated in the A/B/C-TEACH modelling module (see Fig. 1), namely: (a) the Collaboration/Metacognition-Adaptive Fuzzy Model (C/M-AFM), (b) the Collaboration/Metacognition-Adaptive Neuro-Fuzzy Inference System (C/M-ANFIS) model, (c) the Fuzzy Logic-based modeling of the Quality of Interaction (FuzzyQoI) model, (d) the Fuzzy Cognitive Map-based modeling of the Quality of Interaction (FCM-QoI) model, and (e) Block-diagram of an emotion recognition process using EMOTIV EPOC Headset and EEG analysis

4.1 C/M-AFM and C/M-ANFIS Models Contribution: QoC

In general, the C/M-AFM model presents an instructional design (ID) that facilitates the use of FL systems to model the collaborative/metacognitive data that are logged within a computer-supported collaborative (c)-learning (CSCL) environment. At the same time, the QoC is evaluated on the basis of the balanced collaborative activities of adult peers, while they perform asynchronous, written communication within a CSCL environment. The main purpose of this microgenetic modeling (C/M-AFM model) is to provide an individual, intelligent and adaptive support that may further enhance the peers' QoC. In addition, experimental efforts, using the CSCL Lin2k tool [10] revealed the improvement of the collaborative performance, towards its integration with other research areas (e.g., the complexity of the turn-taking between peers for the submission of an interaction while collaborating, the use of quality control analysis to define values of the QoC out of calculated limits, efforts to reveal possible obstacles at the metacognitive level that hinder the QoC).

From a holistic perspective, the C/M-ANFIS model aims at increasing the effectiveness of collaboration between the peers, by providing advice and support on collaboration issues, such as equality of participation, reaching a common understanding [26], and not on task-oriented ones, such as understanding and application of key domain concepts. The support from the C/M-ANFIS model combines two approaches: (i) to provide indicators to the peers, and (ii) to advise them. For the first approach, it uses the collaborative and metacognitive data provided by the Lin2k tool [10] in order to aggregate them into three high-level indicators and graphically display them to the collaborators along with a set of desired values. At this stage, the collaborators are expected to manage the interaction themselves, having been given the appropriate information to do so. Since the displayed indicators express an abstraction of the complex variables of the employed model of interaction, their interpretation and action upon the indicator values by the peers is facilitated. In addition, the peers easily comprehend the displayed indicators without any special analysis that would increase the peer's cognitive load and might lead to misinterpretation of the indicators. The adaptive character of the C/M-ANFIS model further enhances the support to the peers, since their individual collaborative and metacognitive activities have been taken into account by the model. Moreover, constructive feedback (e.g., graphical and text) provides the peer with the information regarding: (i) how the system has judged his/her collaboration, (ii) how s/he has thought about her/his collaboration, and (iii) how the system predicts his/her collaboration for the next step. In that way, a positive impact on peers' metacognitive activities is achieved, supporting the construction and gradual optimization of a shared mental model of interaction. The latter, may encourage peers to regulate their interaction explicitly, leading to a better coordination of the joint effort to reach a solution [27]. For the advisory support, the C/M-FIS/ANFIS models mimic the role of a human advisor in a collaborative learning environment. Actually, the advisor, based on collaborative data, i.e., close observance of group interaction, trial and error, and experience [27] advises the peer, both on his/her current status of collaboration and on the future actions s/he must undertake for further improvement. Similarly, the C/M-ANFIS model, by inferring on collaborative and metacognitive data, foresees the status of collaboration in the next step and offers the peers with tips to improve their interaction and achieve or maintain equilibrium (ideal collaboration). Actually, these tips propose some simple remedial actions, such as "As far as I can tell from your collaboration activity so far and my prediction for the next step, you have to dramatically increase your participation from now on". The tips are drawn from a message-database, which includes messages for achieving, maintaining, and warning, according to the combined values of the three indicators. In particular, big differences between the indicators and the desired value of 50% provoke achieving messages, whereas small ones provoke maintaining messages. In addition, conflicts between the values of the indicators provoke warning messages. The employment of both indicators and advice in the support provided to peers by the C/M-ANFIS model motivates self-diagnose and sustain coaching, forming an efficient support scheme that lead distant collaborators to improve in different ways.

4.2 FuzzyQoI and FCM-QoI Models Contribution: QoI

Overall, the FuzzyQoI model through the dynamic estimation of the QoI, not only has the potentiality to analyze general trends from a macroscopic view, but also has the capability to capture a dynamic phenomenon that evolves during the whole time-period across the academic year, affected by the specific characteristics of each time-period segments, justifying the ability to capture QoI changes at a mesoscopic and microscopic level of resolution. The latter can be adopted as an efficient tool to address the complexity and multi-variability of b-learning environments. By employing the FL to the modeling procedure, it is possible to develop an innovative approach that takes under consideration the human factor and the complex nature of b-learning, in order to result in a quantitative account of this, as expressed by the QoI parameter. As expected, the pathway of systemic analysis can reveal different kind of variations across and/or within courses and disciplines, explaining outcomes from a wide range of system levels that includes all states, taking into account the different circumstances of each level and their complex interrelationships across different academic years. Due to the worldwide adoption of LMS Moodle in the educational practice, the FuzzyQoI scheme could be applicable across a broad spectrum of b-learning environments, and, in general, to online learning systems, providing a common approach for comparative critical analysis. Extending this perspective here, the intermediate estimated fuzzy outputs and the final QoI output of the FuzzyQoI model can be used as indicators twofold, so they that can serve as the basis for the generation process of adaptation features for the LMS (system's response) and evoke metacognitive procedures within the users (like those from the QoC), so they could improve their QoI with the LMS (user's response).

Based on QoI of the LMS users, the FCM-QoI model constitutes a practical implication to the domain of Fuzzy Cognitive Map (FCM) research in the Higher Education (HE) context. From this perspective, based on the concepts that formulate the FCM-QoI model and their causal dependencies, the FCM-QoI model could help pedagogical planners to holistically visualize, capture, understand, and assess stakeholders' needs and their interdependencies. Hence, through its structure and its inference on LMS users' QoI, the FCM-QoI approach could act as ideal mechanism/feedback to support different stakeholder groups (including department heads, teachers, administrators, technical support staff, and students) in the domain of HE. Moreover, it can reveal which factors are believed to have a greater effect on the adoption of online tools in the LMS Moodle, in a kind of simplified and global visualization for all combinations of inputs and output. Under this line, the fuzzy weights express the magnitude of change that a variable may undertake due its causal relationship with other variables; hence, as a holistic and dynamic model, the FCM-QoI approach has the potential to explore possibilities and scenarios from different perspectives.

4.3 Overall Perspective

The implementation, adoption and development of an effective OLE in the context of HE (and training) require contributions, exchanges and sharing experiences to construct, in a medium-long term, an environment that can respond to the specific needs of the learners and teachers, in particular, and to the community, in general. From an ecological point of view, the learners' individual actions need to be understood within interconnected learning environments, combining micro-, meso-, and macro-systems. To this endeavor, the iLMS could provide the means for quantitatively evaluating the learners' activities at the various resolution scales, taking into account the following considerations:

- *Adaptable c-, and b-learning scenarios*: there is still the need to continue to develop c-, and b-learning solutions, especially, more adapted to the requirements of users, to enhance the teaching-learning process, instructional design and its educational offer.
- *Sustainable HEIs encouragements/reinforcements*: it is important to underline that c-, and b-learning approaches will be only successfully used when the advantages of their use become more explicit, requiring, more sustainable institutional incentives.
- *B-learning as a creative thinking*: this work can contribute to the development of an intelligent OLE based on conceptual blending as a creative thinking; the blended concept, although successfully applied in a varied number of fields, has to be examined in a more understandable and detailed way, (re)combining particular elements and their relations into a common sociocultural environment to generate new inferences and new interrelations in further advances in OLEs.
- *OLE techno-pedagogical support and training*: it is essential to continue to develop a relevant scientific work of dissemination and training and even more specialized support, in an effort to understand the cultural/social dynamics, in order to create conditions to efficiently optimize, monitor, evaluate and innovate b-, and c-learning processes/environments.
- *QoI and QoC indices to monitor OLE collaboration and interaction*: the QoC and the QoI in OLEs, seen here through the field of FL modeling, can be used to develop a systemic/panoramic approach, resulting in a quantitative explanation translated by the QoC and QoI indices. The latter can represent a distinct path on approaching OLEs, since, on the one hand, they incorporate human subjectivity and, on the other hand, extend the experiences of monitoring of refined collaboration and interaction processes based on efficient OLE, under the b-learning mode.
- *Alternative and advanced techniques/approaches in education*: the efficiency of the presented models, based on innovative techniques from the fields of fuzzy set theory, neuro-fuzzy modeling, fuzzy cognitive maps, dynamic nonlinear analysis, intended to reveal the trends and dynamics within the QoC and QoI, justifying the adoption of FL in the field of education, encouraging and preparing the way for sophisticated approaches in OLEs-based modeling for c- and b-learning.
- *Effective assessment techniques*: apart from the fast and early educational feedback to the academic institutions to enhance their understanding of the level of OLEs efficiency, important managerial implications could also be tracked through the use

of the estimated QoC and QoI parameters; in fact, OLE managers and pedagogical designers could monitor the measure of QoC and QoI and, via the evolution of the latter, reflect upon issues, like system-quality, system-use and user-satisfaction into their present evaluation techniques of OLE-based b-learning systems efficiency.

- *Applicability to multiple c- and b-learning contexts*: due to the worldwide adoption of OLEs in the educational practice, the related issues discussed in this paper could be applicable across a broad spectrum of c- and b-learning contexts, and in general e-learning systems, providing a common approach for comparative critical investigations. As mentioned before, the A/B/C-TEACH started as collaboration between the Faculty of Human Kinetics, University of Lisbon, Portugal and the Aristotle University of Thessaloniki, Greece. However, A/B/C-TEACH has extended its ties recently with the Khalifa University of Science and Technology (KUST), UAE. In this way, it involves two countries of Europe (Portugal and Greece) and one from Asia (United Arab Emirates).
- *Ecological/inclusive learning scenarios*: the exploration and integration of more ecological (micro-, meso-, and macro) approaches, based on (universal) instructional design principles, specially tailored to the needs of the online users and focused on technological/pedagogical improvements, are required.
- *Affective learning*: the extension of OLEs to the field of affective computing is vital, since emotions have been recognized as an important element in motivation and learning; in this way, combining learners' interaction indices, like the QoC and QoI presented here, with their affective state, captured by intelligent acquisition modules (e.g., facial expression recognition cameras/interfaces such as biosignals-based affective computing devices), new tutoring systems could be formed, providing more personalized, adaptive and intelligent instruction to the learner.

Moreover, alternative approaches can be explored in the future, in order to find ways that effective teaching could be accomplished when bridging the fields of a-/b-/c-learning into a hybrid and enhanced educational environment. Nevertheless, future always seems appealing and the examined hybrid model could further be extended including, for example dynamic nonlinear analysis and affective computing, in order to contribute to the enrichment of the HEIs services and re-examination of educational policies/practices. This idea is further elaborated in the following section.

5 Future Work: Affective Perspective

5.1 Affective Module and Biosensors Approaches

In OLEs, learners do not see teachers' expression of encouraging/criticizing, tending to decrease students' learning interest, in general. From this perspective, within LMS space, emotions should be seen as an important promising approach to encourage and develop positive emotions (motivation and interest) of learners. Actually, the capability to manage feelings and relationships is considered a kind of "emotional intelligence" that enables people to be successful. More specifically, emotional predictors of online success (e.g., emotional self-regulation, self-generated motivation, self-efficacy, internal locus of control) have been closely related with emotional intelligence [28, 29].

According to Tucker et al. [30], emotional intelligence can be included into the curriculum; Goldsworthy [31] has integrated emotional intelligence into online instructional approaches by designing online educational materials for personal emotional skills that sustain motivation, self-confidence, and teamwork when people feel overwhelmed.

From this perspective, biological sensors, such as electrocardiography (ECG), electroencephalography brainwaves (EEG), and eye tracking have been used for the measurement of emotion of learner, providing selective quantitative or semi-quantitative analytical information using a biological recognition element [32]. More recently, Shen, Wang and Shen [33] have also integrated the heart rate (HR), skin conductance (SC), blood volume pressure, and EEG measurements to detect emotions of learner. Interestingly, Kittanakere et al. [34] have introduced the design of an emotion sensitive e-learning system, giving specially emphasis to the learning process. This system categorizes a learner's emotional state as Happy, Neutral, and Sad, generally motivating to think about incorporating emotional aspects of teaching in online learning systems to make it more intelligent. In other words, these emotional plugins (as a set of objects, which the system suggests to be plugged-in to the technical module depending on the emotional state of the learner) can be seen as helpers in modulating the mood of the learner, enhancing the effectiveness of the learning process [34]. Emotion recognition is one of the key steps towards affective computing. In this context, several efforts have been discussed to recognize emotions using facial expressions, speech and physiological signals (e.g., [35]). This field has been boosted recently due to the technological innovation seen in data acquisition devices that could be used in the affective computing. For example, a Bluetooth-based EEG device from Emotiv (www.emotiv.com) is a revolutionary personal interface for human computer interaction, which uses sensors to tune into electrical signals produced by the brain to detect user thoughts, feelings, and expressions. Based on the acquired information from the EEG data, a useful metric for measuring student's emotional state during learning can be obtained. In addition, Emotiv could also assist students with mobility problems to use their brain activity for interaction with the computer, since it provides brain-mouse and brain-keyboard control potentialities (see Fig. 2(e)). In fact, by using the user's affective information (as a combination of HR, gestures/postures and expressions) the opportunity for the OLE to act analogously is obvious, elevating the level of personalization to the user's affective status and performing the appropriate actions to foster his/her receptivity of learning.

From an educational perspective, the main interest is to focus on the emotional aspects of the online systems using biological signals and/or gestural and facial expressions, in order to design intelligent LMSs and tools/activities that avoid inappropriate affective feelings (such as anger, boredom, and anxiety). In addition, more internal issues of learners' system could be explored, when taking into account information from the affective domain. As examples, in a recent study, Hadjileontiadou, Nikolaidou, and Hadjileontiadis [36], propose a modeling scheme of learner's complex system by reflecting Boulding's typology at the affective computing space, whereas Hernández, Sucar and Arroyo-Figueroa [37] introduce an affective behavior model that considers the affect and the knowledge state to provide students with an adaptive and intelligent instruction. In fact, an intelligent OLE should be able to adapt to the knowledge, emotions, learning abilities and needs/preferences of each user. From this perspective, designing OLEs that focuses on user's emotions using affective state information captured from intelligent devices seems to be very promising approach for future re-fined investigations in the field of 21st century learning.

5.2 Affective Module and Sentiment Analysis Approaches

On the other hand, apart from the content, the affective character of chat text interactions in OLEs should also be taken into consideration. In this vein, machine-learning algorithms can be applied to perform extensive text sentiment analysis. The latter is an ongoing field of research in text mining field, being defined as the computational treatment of opinions, sentiments and subjectivity of text [38]. Ongoing work towards such direction includes sentiment analysis of the posts of peers at the LMS Moodle forum based on the use of Long Short-Term Memory (LSTM) units (or blocks), i.e., building units for layers of a recurrent neural network (RNN) [39], after trained on labeled sentiment data from the Stanford MOOC Post database (https://datastage.stanford.edu/StanfordMoocPosts).

The realization of this design infuses Deep Learning approaches into the A/B/C-TEACH concept, enhancing it further to an A/B/C/D(eep)-TEACH approach. From the aforementioned emerging future perspectives, a hybrid approach incorporating text sentiment analysis could be envisioned, fostering a more personalized intelligent, collaborative, adaptive and affective perspective of learning.

6 Conclusions

In this paper, the A/B/C-TEACH project was presented in detail, exploring the ways effective teaching could be accomplished when bridging the fields of affective (a)-, blended (b)- and collaborative (c)-learning into a hybrid, LMS-based, enhanced teaching-learning environment. Practical implications to HEIs and emerging trends about the enhancement of LMS-based teaching/learning processes were presented and discussed, towards the development of an educational and innovative framework around the online instructional environments, by exploring the potentialities of a/b/c-learning/teaching in the context of higher education.

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Sentiment Analysis Techniques and Applications in Education: A Survey

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Abstract. As the interplay between cognition and emotion is involved in every learning process, student profile should be enhanced with information regarding his/her affective state. Sentiment analysis could serve this end, through the analysis of student behavioral traces in teaching-learning environments. The purpose of the present study is to review the status of research on the field of sentiment analysis in the educational domain; exploring different ways in which sentiment analysis has been applied in the educational domain, and analyze the different techniques that researchers have adopted in developing sentiment analysis systems on educational datasets. Five different task types that sentiment analysis has served within the domain were identified, namely: (i) instruction evaluation, (ii) institutional decision/policy making, (iii) intelligent information/learning systems enhancement, (iv) assignment evaluation and feedback improvement, and (v) new research insights. From a technical perspective, a brief explanation of the different sentiment analysis techniques along with representative examples are presented. The character of this work may address the needs of a diverse group of stakeholders, including educators, social sciences researchers as well as researchers, in natural language processing in education.

Keywords: Sentiment analysis · Opinion mining · Natural language processing · Machine learning · Education

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1 Introduction

Human brain is not a purely cognitive information processing system but a system in which affective and cognitive functions are inextricably integrated with one another [1]. This interplay between cognition and emotion is involved in every learning process, with cognition dealing with the learning content, and emotion providing the necessary mental energy [2].

Research on emotion in teaching-learning contexts has followed two different approaches: in the first approach, emotion is one affective domain category that needs to be developed properly while the second approach focuses on the integration of learner's emotions in the teaching-learning context and the appropriate handling of these emotions during the learning process [3]. Empirical evidence suggests that learners do not randomly shift between emotions but there appear to exist some patterns; engaged learners will experience cognitive disequilibrium and confusion when they face difficulties and failure to restore equilibrium triggers frustration [4]. In fact, boredom is found to be the most persistent affective state and difficult to be restored and, hence, it is important to prevent it before it occurs [5].

In contrast to face-to-face teaching-learning contexts, in which problems can typically be discussed and resolved more readily, online learning environments that rely on text-based asynchronous communication may exacerbate the level of student distress [6]. In this context, sentiment analysis, "the task of automatically determining the valence or polarity of a piece of text, whether it is positive, negative, or neutral" [7], is a promising solution. Sentiment analysis could be characterized based on the design criteria for emotion sensing systems distinguished by [8] as a non-obtrusive, non-invasive, low-cost tool, that could serve the enhancement of the student profile with information regarding his/her affective state, through the analysis of his/her behavioral traces (i.e., texts) in teaching-learning environments.

Based on the review of the status of research on the field of sentiment analysis in the educational domain, the aim of the present study is twofold, namely: (i) to explore the ways in which sentiment analysis has been applied in the educational domain; and (ii) to analyze the techniques that researchers have adopted in developing sentiment analysis systems on educational datasets.

In addition, this paper is organized as follows: in Sect. 2, the different task types that sentiment analysis tools have served in the domain of education are identified; in Sect. 3, a categorization and brief explanation of the different sentiment analysis techniques applied on educational datasets are presented, along with representative examples; in the Sect. 4, the problem of the cross-course sentiment analysis is discussed; and finally, Sect. 5 concludes the present work.

2 Sentiment Analysis Applications in Education

2.1 Instruction Evaluation

Student ratings in form of closed-ended, Likert-type questionnaire items is the most common method for instruction evaluation in higher education, even though it is demonstrated that qualitative student feedback sheds light upon factors that quantitative ratings ignore [9]. The higher level of informativeness in combination with the unstructured nature of this form of feedback, as compared to the quantitative one, make its interpretation one of the most difficult tasks and often lead to its dismissal [10]. In this vein, many studies have employed sentiment analysis as a viable solution for analyzing student feedback comments in open-ended questions in evaluation surveys [11–13], for instance, review sites like Rate My Professors [14, 15], or Massive Open Online Courses (MOOCs) reviews [16]. Additionally, sentiment analysis has been proposed for student feedback produced during semesters in order for educators to rapidly meet students' needs and expectations and not to apply changes in forthcoming semesters only. In [17], for instance, sentiment analysis was used in student discussions collected from Moodle's forum and chat during a blended learning-based Information Technology course. The results suggested a positive trend of the positive sentiment across course duration as the teacher was adapting its teaching practices according with students' sentiment, offering more examples and exercises. In the work of [18], a Sentiment Analysis for Education (SA-E) system is proposed for analyzing real-time student feedback during lectures. In this educational system, feedback is offered by students via Twitter anytime or at specific time-slots, determined by the lecturer, to insure that students follow the pace of the lecture and to provide support if difficulties are faced.

2.2 Institutional Decision/Policy Making

The potentialities of sentiment analysis have been tested in academic analytics, a field akin to business analytics, which focuses on the institutional level and targets the needs of administrators, policy-makers, funders, and national governments [19, 20]. In the work of [21] and [22], a sentiment analysis applied on social media is proposed for collecting users' feedback towards universities and for serving as a complementary evaluation and benchmarking approach to university ranking systems. In addition, in the work of Patel et al. [23], parent feedback towards a college was collected during various parents' meetings and was subjected to sentiment analysis in order to provide awareness of the institution's overall functioning. Additionally, sentiment analysis has been utilized for assessing and, accordingly, for improving products and services provided by institutions. In the work of [24], for instance, users' (i.e., learners' and teachers') attitudes towards e-learning systems were analyzed from a variety of e-learning blogs as well as from Moodle-related forums.

2.3 Intelligent Information/Learning Systems Enhancement

Emotion information extracted through sentiment analysis can be leveraged for the creation of learning objects' user-generated metadata and to be integrated into adaptive learning systems, in order to facilitate a more personalized learning experience, based not only on cognitive but also on affective students' characteristics. Scaffidi [25] presented an approach for the automatic recognition of valuable forum messages that provide the solution to a user-specified problem. A sentiment model was used in order to determine if a message is a solution based on the sentiment expressed from the authors of the subsequent messages. The sentiment model outperformed the baseline one, with an error rate of only 18% and an F-measure of 79%. Cummins et al. [26] applied sentiment analysis on written feedback tags attached to student programming assignments, to generate sharable learning resources for identifying different successful and unsuccessful approaches for solving programming problems. Sentiment-based support provided to students from CoMoLE, an adaptive e-learning system, is proposed in the work of [27]. Recommendation of motivational tasks (e.g., games, simulations) to individual students or group members who experience negative feelings, group formation based on the affective state of the students for avoiding coexistence of negative feeling in all group members, and detection of emotional changes are some of the opportunities that sentiment analysis introduces in the e-learning context [27].

2.4 Assignment Evaluation and Feedback Improvement

Studies have investigated the potentialities of sentiment analysis in providing automatic summative assessment and emotion literacy in feedback. In work of [28] sentiment analysis is proposed for evaluating students' essay quality, as argument construction in essays relies on the presence of opinionated and sentimental statements. Additionally, building upon the difficulty in which the communication of the written feedback between its producer (i.e., teacher/peer) and its receiver (i.e., student) fails in terms of the intended attitude, Cummins et al. [26] proposed the augmentation of written feedback with information regarding the sentiment of its producer.

2.5 New Research Insights

Sentiment analysis is a learning analytics method [29] that, at the same time, can provide valuable research opportunities in the fields of learning analytics and educational data mining themselves. Through combinatorial analytics, namely, multiple analytics each of which adds to the contextual insight, researchers have unprecedented opportunities to investigate patterns [20]. In this vein, researchers have employed sentiment analysis in order to investigate whether sentiment ratio in MOOCs correlates with dropout in course-level and user-level [30], to predict whether a student will drop out from a MOOC the subsequent week [31], to investigate correlations between social network structures in student discussions and degree of controversy [32] as well as correlations between student sentiments and performance [33].

3 Sentiment Analysis Techniques

3.1 Lexicon-Based Approach

Sentiment and opinion words are often the dominating factor in the task of sentiment classification and, hence, are often used for this purpose in the unsupervised manner of lexicon-based approach [34]. In lexicon-based approach, sentiment classification is performed using a sentiment dictionary, a collection of lexical units accompanied with their sentiment orientation, where lexical units may be words or phrases and sentiment orientation may be coarse classes (e.g., positive, negative), fine-grained classes (e.g., varying from very positive to very negative) or real values in an interval such as [−1, +1] [35].

In the work of [30] a lexicon-based approach was adopted for sentiment classification of students' posts related to predetermined topics (e.g., course, lecture, assignment) in three MOOCs. In this study, Bing Liu Opinion Lexicon [36] was incorporated and each topic's sentiment orientation was computed as the ratio of positive versus negative words used in the topic-related posts in a given day. As topic sentiment dynamically changes across days, moving average of topic sentiment ratio over a window size of k past days was used as a smoothing technique. In addition, a different lexicon-based mechanism was used for computing sentiment orientation in student feedback comments [37]. In this mechanism, emotion vectors derived from the NRC Emotion Lexicon [38] were employed and sentiment was computed from six of the emotion vectors' parameters (i.e., joy, trust, anticipation, anger, disgust, sadness), which were identified as contributing to positive or negative sentiment with different weights.

Although lexicon-based approach claims to be domain-independent, it cannot efficiently capture domain and context-related knowledge [34]. Studies have tried to address this problem by building education-specific lexicons instead of using general-purpose ones. In the work of [39], for example, seed words related to teacher evaluation (i.e., helpfulness and clarity) were expanded searching their synonyms (i.e., positive terms) and antonyms (i.e., negative terms) in Wordnet. The resulted dictionary was employed in order to determine the sentiment polarity of student comments in the Rate My Professors website by counting the number of positive and negative words found within them. Rajput et al. [40], adopted the MPQA lexicon [41] to words' sentiment polarity when they appear into educational contexts (e.g., the original polarity of the dictionary entry "lecture" was modified from negative to neutral), in order to classify students' feedback comments into positive, negative or neutral. Each comment's sentiment score was computed as the sum of its constituent words' polarity, with the latter calculated as word's frequency of appearance in the comment multiplied by its orientation in the dictionary.

In contrast to lexicon-based methods, which are restricted to human-interpretable knowledge, machine learning approach uses algorithms that automatically learn from different types of features through optimization [34]. In the next subsection, machine learning techniques for solving sentiment classification tasks in the domain of education are presented.

3.2 Machine Learning-Based Approach

Machine learning-based approach relies on machine learning algorithms and uses linguistic features [42]. Depending on the feedback, being available to the algorithm to learn from, learning can be characterized as supervised, unsupervised or weakly-supervised. In the following subsections, a brief explanation of the differences between these types of learning is presented, along with representative examples of studies applying related techniques on educational datasets.

Supervised Learning. In supervised learning, the actual status (i.e., sentiment class) for each text instance in the training set is known and, hence, this type of learning can be considered as a function fitting task based on some data points [43]. Features for representing the input text as well as the learning method applied are two crucial points for effective sentiment classification [44].

Features. N-grams are one of the most frequently applied features for representing the input text. N-grams are sequences of n terms in a given text, with n = 1 denoting single words (unigrams), n = 2 denoting the contiguous co-occurrence of two words (bigrams), and so on. As negation phrases can be considered a special case of n-grams [45], bigrams are exploited for negation handling [46]. Nasim et al. [47] in have compared unigrams, bigrams, and unigram-bigram combination and the results of their study suggested that unigrams were the most effective. Similarly, in [48] and [15] works, simple unigrams outperformed higher-order n-grams. On the other hand, trigrams and unigram-bigram combination outperformed unigrams and bigrams in works of [49] and [14], respectively.

Lexicon-based knowledge is, also, incorporated into machine learning algorithms, formulating hybrid approaches. In work of [14], for instance, lexicon terms found in three different lexicon resources (i.e., OpinionFinder [50], a subset of WordNet Affect [51], and General Inquirer [52]) were extracted from the input text and were used to formulate unigrams and bigrams; however, raw n-grams proved to be more effective. In the work performed by Nasim et al. [47] a modified version of MPQA [41] subjectivity lexicon, introduced in [40], was employed for computing text sentiment score by subtracting the count of negative words from the count of positive words. Classification performance improved when all different features tested (i.e., unigrams, bigrams and Term Frequency-Inverse Document Frequency) were combined with lexicon scores rather than when they were individually applied. Dalal et al. [15] applied an hybrid approach of linear lexicon-pooled Naive Bayes, combining the probability distributions from Naive Bayes with lexicon-based knowledge.

The parts of speech (POS) that words belong to are another type of classification features. In work of [53] POS tagging was performed as a pre-processing technique and all POS tags were used as features while in others only specific POS, such as adjectives [11, 15], adverbs and verbs [11] were extracted and treated as special features. POS patterns and lexicon terms were used in works performed by [15] and [54], in order to extract sentiment phrases and regulate sentiment shifters such as intensification.

Syntax, frequency-based and interaction-related features are composite feature sets that have been used for analyzing sentiment in interactive, turn-level student discussions [55]. Syntax features were built upon three different feature categories, namely, bigrams, POS and their positions in the sentence, as well as sentence structure (simple/complex) and the kind of complex sentences, indicated by eight types of conjunctions. Frequency-based feature set included statistical features in a given sentence, such as the length of the sentence, the number of characters and the frequency of punctuations, unigrams and bigrams, positive and negative emotion terms, functional words, nouns, and verbs. On the other hand, interaction-related features' set included, for instance, non-language symbols, time-related features, mimetic words, modal particles, interlocutor's gender, and topic of discussion.

Learning Method. N-grams In typical learning methods, the prior trained algorithm outputs a classifier, namely a hypothesis about the true function that maps a given input text to one of predefined categories (i.e., sentiment classes) [56, 57]. Learning algorithms applied in studies performing sentiment classification in educational datasets include Naive Bayes [11, 12, 14, 15, 49, 55, 58–60], Support Vector Machines [12, 14, 16, 28, 49, 55, 59], Decision Trees [28, 55, 60], Logistic Regression [28, 49, 58], and K-Nearest Neighbour [11, 12]. Moreover, the performance of different algorithms (i.e., Naive Bayes, Complement Naive Bayes, Maximum Entropy and Support Vector Machines with linear, polynomial and radial kernel) was compared and Support Vector Machines with radial kernel substantially outperformed [61]. Although performance decreased for most classifiers in three-class classification (i.e., positive, negative, and neutral) as compared to binary classification (i.e., positive, negative), for Support Vector Machines with radial basis kernel the difference was only 1%. Additionally, although Naive Bayes had the lowest performance, Complement Naive Bayes dealt successfully with the unbalanced dataset used in the study, and exhibited high performance. Similarly, Support Vector Machines outperformed Naive Bayes in works of [49, 62], and [63] while, conversely, Naive Bayes achieved higher classification results in [14].

Ensemble learners, namely a set of classifiers whose hypotheses are combined [56], have attracted the interest of the research community due to their generalization abilities [44]. In this vein, ensemble learning methods have been investigated for sentiment analysis on the educational domain, as well. In the work performed by [60], voting-based ensemble of ID3, J48 and Naive Bayes outperformed each of these three algorithms when they were used individually. Cost-sensitive Random Forest and multi-class meta-classifier outperformed Support Vector Machines and Naive Bayes in works of [54] and [55], respectively, while Support Vector Machines and Random Forest exhibited competitive results in works of [47] and [59]. AdaBoost, on the other hand, did not outperformed Support Vector Machines and Naive Bayes [59].

Artificial Neural Networks is another class of learning methods adopted by researchers in the field. In work of [64], different architecture types of neural networks, such as convolutional neural networks and long short-term memory networks, are compared while radial basis function network and multilayer perceptron were used in works of [12] and [55], respectively.

Unsupervised and Weakly-Supervised Learning. As annotation of training data with sentiment labels is a cost-inefficient process, unsupervised and weakly supervised approaches have been investigated as a solution. In unsupervised learning the system learns patterns in the input even though no explicit feedback is supplied [65]. On the other hand, weakly-supervised learning is an umbrella term covering a variety of studies that develop models by learning with weak supervision such as incomplete, inexact and inaccurate supervision [66].

Bashri and Kusumaningrum [58], adopted an unsupervised learning approach for analyzing sentiment in students' comments towards their university. More specifically, Latent Dirichlet Allocation (LDA) topic modeling was used to determine the word-topic probability while sentiment polarity was calculated based on the total word-topic probability value of positive and negative words found in a sentiment lexicon.

The proposed unsupervised model was compared with supervised learning-based classifiers (i.e., Naive Bayes, Logistic Regression) and outperformed in terms of F-measure.

Ramesh et al. [67], in order to address the problem that topic models may capture general topics, such as the ones related to the course contents, incorporated a variant of the LDA model using seed words (SeededLDA, proposed in [68]). Through this type of weak supervision, educational domain-specific knowledge was encoded, related to coarse aspects (e.g., lecture, quiz), fine-grained aspects (e.g., lecture-video, lecture-lecturer), positive, negative and neutral sentiment polarities, common course problems that are associated with sentiment (e.g., difficulty, availability) and course syllabus-specific topics (e.g., java, software). Additionally, the authors developed a joint aspect-sentiment model using Probabilistic Soft Logic (PSL-Joint), which reasons upon the SeededLDA and captures the dependencies between sentiment and aspect, using weighted logical rules. Validation of both weakly-supervised models on student posts from different Massive Open Online Courses demonstrated that PSL-Joint model outperforms the SeededLDA-based one.

4 Cross-Course Sentiment Analysis

Sentiment classification is a domain dependent and context-sensitive task [69]. In fact, it has been demonstrated that dependency in sentiment classification can take the form of domain, topic, time period and language style [70]. In the domain of education, dependency may take the form of course discipline and content. Wen et al. [30], for example, used a lexicon-based sentiment analysis method, in order to determine sentiment in students' discussions in three different MOOCs and findings suggest that in a Fantasy and Science Fiction literature course, negative comments were the ones in which students were describing characters in fictions.

In this vein, cross-course sentiment classification, i.e., training on one course and testing on the other, was investigated in works of [59] and [64]. Bakharia [59] suggested that a classifier trained on Humanities dataset was the one with the best in-discipline performance but also the most successfully transferred one, with a small loss in accuracy, while the classifier with the poorest in-discipline (i.e., Medicine) performance could not generalize well in other disciplines, with an accuracy drop of up to 20%. Wei et al. [64] proposed a combination of the convolutional neural network with the long short-term memory network (ConvL) as a transfer learning approach for cross-discipline classification. More specifically, model parameters trained on the source discipline were used to initialize the target discipline and then were fine-tuned with smaller amounts of target discipline data. ConvL was compared with other deep learning approaches, that incorporated or not a transfer learning scheme, and results indicated that this approach was the most efficient, producing competitive results with the same model when tested in source course. Factors that could enhance the effectiveness of the model included word embeddings trained on educational dataset instead of other domain data, participation of more layers in parameters fine-tuning, fine-tuning on greater proportions of target domain data, and source data originated from a single course rather than merging data from multiple courses.

5 Discussion

This work presents a systematic literature review, in order to provide an overview of the current state of research on machine learning-based sentiment analysis of educational datasets. The focus of this review only on educational datasets may seem rather restrictive. However, this loss in range is inevitable in order to gain the in-depth view of the inter-domain research approaches. Domain-specific knowledge is prominent in sentiment analysis as each domain has its own desirable and undesirable situations that differ from the ones of other domains [34]. Social media texts, for instance, usually contain misspellings, letters repeated for emphasis (e.g., “looove” instead of “love”), hash-tagged words, emoticons, and abbreviations, which introduce a lot of noise in data, although many of these terms convey emotions [7]. Thus, sentiment analysis applied in social media, such as Twitter, presents the special challenge of the proper cleaning and noise reduction in data without losing valuable sentimental information. In the political domain, on the other hand, the use of sarcasm and irony are common phenomena; their detection, however, can be difficult [7]. From the aforementioned it follows that sentiment analysis, as a natural language processing task, is highly challenging and a uniform, standard solution does not exist. In order to gradually accomplish the design of general solutions, understanding of a large number of diverse application domains is needed in the first place [34]. Consideration of the following points, evoked from the results of this systematic review, may contribute to this direction for future studies that will approach sentiment analysis on the domain of education as a machine learning problem.

5.1 Validation Issues

Selection of the appropriate metric is an essential part of the model evaluation process. Although a detailed description of the measures used in text classification problems in general and in sentiment classification particularly is out of the scope of this study, consideration of two main points is recommended when evaluating the performance of a classifier, namely class distribution and classifier’s properties based on the learning setting. As the performance of a classifier heavily depends on the quality of the dataset used for training and testing [71], information regarding datasets should be provided thoroughly in studies conducting sentiment analysis. Information regarding class distribution is fundamental as, in case of unbalanced classes, Accuracy is not considered to be a reliable metric and other measures should be applied [72]. Specifically, Accuracy is invariant under exchange of positive and negative examples and this makes it insensitive to performance on a specific class and to asymmetry of classification, in contrast to Recall, Precision and F-measure [72]. Secondly, most studies report classification performance only on positive class, in terms of Precision, Recall or F-measure. Due to their origin from the field of Information Extraction, these metrics are focused on determining the classifiers’ ability in retrieving the positive examples, while correct classification of negatives is ignored [72]. In some settings, positive examples are more important (e.g., spam mail recognition) and the above property of these metrics serves the goal of the task, while in others negative examples are also or even more important [72]. When applying sentiment analysis on educational settings the goal is usually to timely detect students' negative feelings, in order to adjust the teaching-learning process before these feelings overwhelm students. In this case, a classifier that successfully detects positive sentiment, but it can not differentiate between negative and neutral sentiment is essentially inadequate. In a different scenario in which students' both positive and negative sentiments have the same weight, negative Recall (Specificity) in combination with other metrics, or Balanced Accuracy separately, would be appropriate in order to reflect the classifier's ability to identify correctly the negative sentiment, as well [72]. From the aforementioned it follows that, as in the field of sentiment analysis positive class is not usually the only focus, information about classifier's performance on other classes should be reported as well.

5.2 Technical Perspective

Sentiment analysis on educational datasets is almost exclusively approached as a supervised learning problem and, as such, it is grounded on the engineering of effective features [34]. N-gram models are the most common features used in the selected studies for representing the input text. However, in some settings higher order n-grams [73] and the combination of different n-gram models [73] achieve better results. Similarly, the findings of this review suggest that, although unigrams outperform bigrams in many cases, trigrams and n-grams combinations are sometimes more effective. Additionally, as negation phrases can be considered a special case of n-grams [73], bigrams are often exploited for negation handling. Deeper linguistic features, namely syntactic relations, as well as composite feature sets that include frequency-based and interaction related features are proposed in studies examining sentiment analysis on interactive, turn-level student discussions. Regarding hybrid classification approaches, in which machine learning is combined with lexicons, the type of knowledge extracted from the lexicon and the dataset size seem that affect the classification results. A significant amount of studies applies feature selection methods, but few examine the effect of dimensionality reduction in classification performance. The vast majority of the reviewed studies focus on the comparison of different algorithms' performance. Naive Bayes and Support Vector Machines (SVM) usage predominates. In [42] it was, also, found that these two are the most frequently used algorithms for solving sentiment classification problem. When compared to other algorithms, SVM often outperform. According to [74], SVM succeed in many text categorization tasks due to their four principle advantages, namely robustness in high dimensional spaces and sparse data, relevance of features, and linear separability of most text categorization problems. However, when deeper linguistic features rather than shallow ones are considered, it seems that SVM fail to succeed while, in contrast, the capabilities of ensemble learners are promising [75].

5.3 Context-Related Issues

Most educational datasets comprise of student feedback regarding courses and teacher performance. Besides education domain, user evaluations are the overall focus of most sentiment analysis studies [37]. In [42], authors, conducting a survey on sentiment analysis techniques, report that the data used in the field are mostly on product reviews.

The predominance of evaluations is perhaps due to their opinion-rich nature and, hence, the lower degree of difficulty in dealing with this form of text [34]. However, in order to develop sentiment analysis systems that are generalizable and applicable in real-world educational scenarios future research should focus more on data produced in real-world teaching-learning settings, such as interactive exchanges between students in distance collaborative tasks or discussions in course forums across semesters. Moreover, the linguistic differences that are presented in students' utterance when they communicate through different means (e.g., synchronous communication in chats versus asynchronous communication in forums) and the potential challenges that they introduce to sentiment classification needs further investigation. Additionally, sentiment classification in education exhibits a special challenge; the inter-domain data diversity due to the different academic disciplines and course contents. In [76], for example, a lexicon-based sentiment analysis method was used in order to determine sentiment in students' discussions in three different Massive Open Online Courses and findings suggest that in a Fantasy and Science Fiction literature course, negative comments were the ones in which students were describing characters in fictions. Thus, the academic discipline that student-generated texts refer to is important. However, one quarter of the reviewed studies do not provide relevant information while a great number of datasets are multidisciplinary. According to [42], there is lack of research in the field of context-based sentiment analysis as most studies use domain-independent corpora for the simplicity in building them. Similarly, as researchers conducting sentiment analysis in the domain of education build and annotate their own datasets, merging data from different disciplines is more convenient. However, in order to foster understanding on how different course contents may affect the classification results and whether transfer learning between courses is a viable solution, future studies should focus more on context-based sentiment analysis in the educational domain.

6 Conclusions

This literature review survey provides insights into the practical implementations, as well as important technical perspective of sentiment analysis in the educational domain, in particular. With its twofold character, this work addresses diverse groups of stakeholders. Firstly, educators are introduced to the pedagogical implications of sentiment analysis as a tool for improving their courses and teaching practices, elevating the level of personalization through the consideration of students' affective state as well as for providing assessment and feedback. Secondly, social sciences researchers may consider sentiment analysis as an alternative emotion measurement tool for investigating emotion-related research issues in teaching-learning contexts. Finally, newcomer researchers in natural language processing in education may gain an understanding of the sentiment analysis techniques applied on educational datasets. Nonetheless, this survey serves more as a literature indicator of research perspectives and it is not a comprehensive overview per se. Future studies should apply systematic efforts, in order to shed light upon the range of the potential applications as well as the techniques of sentiment analysis in education and in other domains of interest.

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Learning Technologies

Tablets and Geography. Initial Findings from a Study in Primary School Settings

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Abstract. The study examines whether the use of tablets can improve the performance of sixth-grade primary school students in the course of Geography. Four teaching interventions were planned and carried out in three groups of students (twenty-two in each), in primary schools in Athens, Greece. While students in all groups worked in pairs, the first used the textbooks, the second used computers and the third was taught exclusively through the use of tablets and micro-applications developed by the class's teacher. The learning outcomes of the third group were equally good compared to the ones of the second, while both groups outperformed the first one. No notable differences regarding students' misconceptions were observed. The results can be attributed to a number of factors such as students' increased motivation and autonomy, but also highlight the need for finding more efficient methods for integrating tablets into the teaching process.

Keywords: Geography · Misconceptions · Primary school

1 Introduction

One of the challenges science education faces is that of poor students' performance. Indeed, students of all ages have significant problems in science-related courses and their performance level is far from being considered as optimal [1]. On the other hand, it is widely accepted that ICT offers noteworthy advantages and opportunities for improving students' learning compared to conventional teaching. This also holds true for science courses; numerous ICT applications do exist, covering a wide range of topics. Moreover, due to technological advancements, devices with educational potential, such as tablets, are becoming increasingly affordable, allowing their en masse use in education.

Based on the above, it was considered an interesting endeavor to design and implement a project for examining the learning outcomes when teaching Geography to sixth-grade primary school students using tablets. The ultimate goal is to examine all the topics/units included in Geography's program of study for primary school and to test a variety of teaching methods. In the coming sections, the results of the first stage of this effort are presented.

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2 Geography as a Teaching/Learning Subject

The goals of teaching Geography to primary school students are -more or less- the same in every educational system. Among them are to inspire students' curiosity about the world and its people, to equip them with knowledge about diverse places, people, resources, natural, and human environments, and to help them understand the Earth's key physical and human processes [2]. Because of the above, three major domains of desired learning outcomes are identified (a) knowledge (e.g., facts, concepts, and theories), (b) skills (e.g., work with maps, make observations, ask geographical questions, and perform field work), and (c) attitudes (e.g., enjoyment, pleasure, interest, confidence, and effort) [3]. Alas, there are many problems related to the teaching of Geography in primary level, with the first one being its weakening position within the curriculum, because more emphasis is put on the core subjects [4]. Indeed, in Greece's primary education, Geography is taught just for one hour per week and only to the last two grades.

While teachers report minor or no problems when teaching Geography [5], the truth is quite the opposite. Research suggested that the depth of their geography subject knowledge and understanding is shallow [6] and that they have the tendency to avoid teaching causal explanations, reasoning, and higher order thinking within geography lessons [7]. In other words, the majority of teachers are not experts in geography, probably because during their studies they received little (or no) training in this subject [8].

Students' misconceptions are another cause for concern. For example, they think that earthquakes occur only in tropical regions, that there is no snow in volcanoes, and that there is a giant magnet in the center of the Earth [9]. Geographical terms such as "valley", "river", and "mountain" are sometimes hard to define or understand [10]. Bisard, Aron, Francek, and Nelson [11], noted several errors when students were asked to identify continents or countries on a map. For overcoming these problems, Catling and Martin [12] suggested that teachers have to stimulate students' interest so as to view Geography as a subject which relates to their daily spatial experiences and to view Geography as a way of thinking. Sadly, in reality, students associate this course with a lot of reading and writing and do not enjoy answering questions from worksheets or textbooks and taking notes. Thus, another way to overcome problems related to the teaching of Geography is to provide powerful learning environments to them. Such environments (a) contain authentic and rich contexts and tasks, (b) stimulate active, cooperative as well as independent learning, and (c) the curriculum is adapted to the needs of the individual students [13].

3 Geography as a Teaching/Learning Subject

Mobile devices (including tablets) provided unparalleled access to communication and information due to their increased affordability and functionality. In an educational context, they enabled new forms of learning known as mobile learning [14] and/or ubiquitous learning [15]. That is because their portable nature allows them to be used virtually everywhere and anytime. Mobile learning can easily and effectively enhance traditional teaching models by providing additional/alternative teaching activities [16].

The existing body of research acknowledges mobile devices' positive impact on students' learning even at very young ages [17]. The key benefits include, but are not limited to, personalized and independent learning, development of metacognitive skills [18], motivation for learning and enjoyment [19, 20], increased degree of collaboration [18], the opportunity to constantly assess and reflect on the learning progress, and greater autonomy [21]. On the negative side, mobile devices can be a source of distraction for students because they tend to use them for non-educational purposes during lessons [22].

Coming to tablets, much of the research on them replicates the findings from studies on other mobile devices. On the other hand, it seems that they have certain advantages over other mobile devices (e.g., larger screens, greater processing, and battery power) and each year they are becoming more affordable since their prices constantly decline. Despite this fact, their educational impact is still largely unknown because of the absence of thorough empirical studies which assess their impact on learning/teaching [23].

The tablet-to-student ratio is also an issue in which research has not given a definite answer. While it is true that low device-to-student ratio may act as a barrier for fully realizing the potential of tablets [24], it is also true that when shared and not used as personal devices, a positive impact on learning was observed [22]. Also, personal ownership and/or the ability to take tablets at home, increased students' motivation, autonomy, and self-efficacy [25].

4 Method

Based on what was presented in the preceding sections, a project was designed for teaching Geography using tablets, having as a goal to examine the learning outcomes. The whole effort was based on the assumption that tablets can function as mediators between students and the learning material, allowing the former to have a better understanding of the subject while working in an environment which encourages engagement, cooperation, and self-regulation of the learning process. On the basis of the above, the following research hypotheses were formed:

- H1. The use of tablets, yields better learning outcomes, compared to other teaching approaches which may or may not be technologically enhanced.
- H2. The sustainability of knowledge is also better.
- H3. The results are also better regarding students' misconceptions.
- H4. Students form positive views and attitudes for their teaching using tablets.

4.1 Participants and Duration of the Project

A quasi-experimental design, with one experimental and two control groups, was chosen because data were collected from intact classrooms. The target group was sixth-grade primary school students (ages 11–12) who (a) never before used tablets as part of their teaching, (b) reflected the spread of ability in a typical Greek sixth-grade class, and (c) the ratio of boys and girls was close to that of a typical Greek primary school. Thus, an “ordinary” and “typical” sample was achieved [26]. The majority of schools which responded affirmatively to the relevant email invitation to participate in the project (addressed to primary schools in Athens, Greece) had to be excluded because they were (a) too far apart and (b) private schools and the sample would be heterogeneous in terms of the socioeconomic status of students. As a result, a total of sixty-six students were recruited from three sixth-grade classes of three neighboring public primary schools. In each class, a teaching method described in the “Procedure” section was randomly assigned. Written consent from students’ parents for their children’s participation was obtained.

The project lasted for about a month (four sessions in each class, from mid-October to late November 2017). Each session lasted for two teaching hours (instead one) so as students to have enough time at their disposal for conducting the session’s activities.

4.2 Materials

Four teaching units from the sixth grade’s school textbook were selected for the project, namely Earth’s (a) continents and oceans, (b) atmosphere, (c) climate zones, and (d) vegetation zones. Since there is an official and freely available online/interactive version of the textbook, it was decided to use it as a basis for the project’s material and not deviate from it (i.e., by adding additional information). Thus, for reasons elaborated in the coming section, four presentations were developed (one for each unit) which included all the multimedia features (images, videos, interactive maps, etc.) of the corresponding units in the online e-book.

The next step was the development of the tablets’ applications. For that matter, Blippbuilder (https://web.blippar.com/) was used, which enables the rapid (and easy) development of applications for mobile devices that fall into the category of Augmented Reality (AR) applications. In short, AR is a technology that merges the real with the digital world by presenting to the user, in real time, a combination of real and virtual objects, multimedia elements, and information, while allowing his/her interaction with the above [27]. A marker (an image) is used for triggering/starting an AR application. Thus, a total of 32 images were used as markers and an equal number of AR micro-applications were developed (an average of 8 micro-applications per unit). Each AR micro-application presented a short passage from the textbook (usually a paragraph, a set of terms or definitions) together with the relevant Google interactive maps, videos, and images. Also, a number of Google forms was developed for the corresponding activities in the e-book. Finally, links were provided so as students to be able to run the external applications which were included in the e-book. The markers were later printed and handed to students who were going to use the tablets. It has to be noted that the micro-applications were not developed by a group of experts but by the class’s teacher who had no previous experience in the development of such applications. The development of the micro-applications required around forty hours (an average of ten hours per unit).

4.3 Procedure

For science subjects, it is recommended students to work in small groups [28]. Accordingly, it was decided students to work in pairs, but since the project was able to provide a sufficient number of tablets, students had their own at their disposal. Also, students were free to take their tablets at home, totally replacing their textbooks (which were left at school during the duration of the project), as other researchers suggested [29]. Increased autonomy and control over their learning pace were also considered as essential [30]. Thus, in each session, after a very short introduction by the class's teacher, students used the tablets and studied the relevant material totally by themselves. They were free to run any micro-application in any order and for as long as they liked, keep notes, collaborate, discuss, and exchange ideas, while the class's teacher provided only technical assistance. The only prerequisite was that each pair of students, by the end of each session, had to be able to present to the rest of the class the answers to the relevant exercises or activities.

In order to compare the learning outcomes of the above teaching scheme, two more groups of students were formed. The teaching scheme in the first group was exactly the same as in the tablets' group with three exceptions (a) instead of using tablets, students used computers (one for each pair) for viewing the relevant units from the online/interactive e-book, (b) the textbooks could also be used (either at school or at home), and (c) the class's teacher acted as facilitator of the process by constantly discussing or collaborating with students. To the second group, the teacher made a short introduction, followed by presentations (using the class's video projector) regarding what students were about to learn. Next, students worked in pairs by studying the relevant unit in their textbooks and by completing the exercises and activities. As in the previous group, the class's teacher acted as facilitator of the process by discussing or collaborating with students. This method is -more or less- the prevailing one in Greece's primary schools.

4.4 Instruments

For data collection purposes, a total of six evaluation sheets were devised (pre- and delayed post-tests, and one for each of the four teaching units), consisting of multiple choice, yes-no, fill-in-the-blanks, and open-ended questions. All evaluation sheets were structured so as (a) to fully cover the content of each unit, (b) questions to be of escalating difficulty, and (c) about half of the questions to check knowledge acquisition and the other half to check whether students could apply this knowledge and required a certain degree of critical thinking and skills, thus, covering two of the major domains of desired learning outcomes [3]. Also, a questionnaire was administered used in previous studies for evaluating students' experiences and views regarding the use of tablets [31, 32], consisting of fifteen five-point Likert-type questions (worded "Strongly Agree", "Agree", "Neutral", "Disagree" and "Strongly Disagree").

Finally, two more tests were formulated in order to check whether the teaching approaches had an impact on students' misconceptions. The questions were inspired by common students' misconceptions regarding the Earth's continents, oceans, atmosphere, climate, and vegetation zones (which were the teaching units that students were taught), as discussed in the relevant literature [33–36]. It has to be noted that the questions in these tests were four-tier multiple-choice questions. For each question, the first tier had a set of three possible answers. The third tier had a set of three possible explanations for each answer to the first tier. In the second tier, students were asked to give their confidence level (sure/not sure) for the first tier, while the fourth asked students to give their confidence level (sure/not sure) for the third one. This was done because the literature suggests that such tests can accurately measure students' misconceptions [37]. For example, a question related to oxygen was the following:

- Most of the Earth's oxygen comes from (a) land plants, (b) sea plants, (c) volcanoes. Are you sure? Yes, I'm sure, Well, not so sure
- You selected (a) because: (i) rain and boreal (snow) forests cover huge areas (more than 1,000,000,000,000 trees), this means a lot of photosynthesis, (ii) there are more land plants (including grass and other small plants) than sea plants, (iii) water blocks sunlight; sea plants' photosynthesis is limited.
- You selected (b) because: (i) there are more plants in the sea (including the microscopic ones) than in the land, (ii) the chemical structure of sea plants' chlorophyll is more complex; sea plants photosynthesize more efficiently, (iii) water facilitates photosynthesis; sea plants photosynthesize far more than land plants.
- You selected (c) because: (i) volcanic eruptions release into the atmosphere tremendous amounts of gases trapped into the Earth's crust, including oxygen, (ii) lava's temperature breaks down carbon dioxide; huge amounts of oxygen are released during this process, (iii) in fact, the most common element found in the Earth's rocks is oxygen (46.6%); when rocks are melted (lava) this oxygen is released.

  Are you sure? Yes, I'm sure, Well, not so sure

5 Results

As presented in the preceding section, the study's sample (sixty-six students) was divided into three groups of equal size: Group1 conventional teaching, Group2 teaching with computers, and Group3 tablets group. Scores in all the evaluation sheets were computed on the basis of the number of correct answers. Mean scores and standard deviations per group of participants and per evaluation sheet are presented in Table 1.

One-way ANOVA tests were to be conducted to compare the scores of the three groups, in order to determine if they had any statistically significant differences. Prior to conducting these tests, it was checked whether the assumptions for ANOVA testing were violated. It was found that: (a) all groups had the same number of participants ($N = 22$), (b) there were no outliers, (c) the homogeneity of variance was not violated, as assessed by Levene's Test of Homogeneity of Variance, and (d) in some tests the data were not normally distributed, as assessed by Q-Q plots and the Shapiro-Wilk test. On the other hand, the literature suggests that ANOVA is robust to moderate deviations from normality and the false positive rate is not affected very much by this violation

[38]. Since the violations were minor, they were considered as acceptable deviations from the assumptions for ANOVA testing.

Given that all the other assumptions were met, the analysis was conducted. It was found that in the pre-test [$F(2, 63) = 0.95$, $p = 0.39$], pre-misconceptions test [$F(2, 63) = 1.14$, $p = 0.33$], ES1 [$F(2, 63) = 2.90$, $p = 0.14$], and post-misconceptions test [$F(2, 63) = 2.42$, $p = 0.10$] there were no statistically significant differences between groups. In contrast, in ES2 [$F(2, 63) = 11.18$, $p = 0.001$], ES3 [$F(2, 63) = 15.85$, $p < 0.001$], ES4 [$F(2, 63) = 12.42$, $p < 0.001$], and delayed post-test [$F(2, 63) = 15.09$, $p < 0.001$] there were statistically significant differences between groups.

Table 1. Means and standard deviations per group of participants and per evaluation sheet.

	Group					
	Group1 (N = 22)		Group2 (N = 22)		Group3 (N = 22)	
	M	*SD*	*M*	*SD*	*M*	*SD*
Pre-test (max = 35)	13.75	2.48	14.46	2.22	13.38	3.15
Pre-misconceptions test (max = 20)	6.55	2.31	7.16	2.55	6.18	1.55
ES1 (max = 25)	14.18	4.15	16.54	3.84	16.89	4.19
ES2 (max = 25)	16.11	3.45	18.52	2.99	20.66	3.12
ES3 (max = 25)	13.78	4.15	17.12	3.20	20.04	3.66
ES4 (max = 25)	17.69	3.50	21.51	3.18	22.88	4.01
Delayed post-test (max = 35)	19.87	3.12	23.11	4.02	25.98	3.87
Post-misconceptions test (max = 20)	11.85	2.19	13.58	3.11	12.66	2.44

Note. ES = Evaluation sheet

Post-hoc comparisons (using the Tuckey HSD test) were conducted on all possible pairwise contrasts in the tests where statistically significant differences were noted. It was found that:

- ES2. Group3 ($M = 20.66$, $SD = 3.12$) outperformed Group1 ($M = 16.11$, SD = 3.45, $p < 0.001$) but not Group 2 ($M = 18.52$, $SD = 2.99$, $p = 0.075$). Also, Group2 outperformed Group1 ($p = .039$).
- ES3. Group3 ($M = 20.04$, $SD = 3.66$) outperformed both Group2 ($M = 17.12$, $SD = 3.20$, $p = 0.029$) and Group1 ($M = 13.78$, $SD = 4.15$, $p < 0.001$). Also, Group2 outperformed Group1 ($p = 0.011$).
- ES4. Group3 ($M = 22.88$, $SD = 4.01$) outperformed Group1 ($M = 17.69$, $SD = 3.50$, $p < 0.001$) but not Group2 ($M = 21.51$, $SD = 3.18$, $p = 0.418$). Also, Group2 outperformed Group1 ($p = 0.002$).
- Delayed post-test. Group3 ($M = 25.98$, $SD = 3.87$) outperformed both Group2 ($M = 23.11$, $SD = 4.02$, $p = 0.032$) and Group1 ($M = 19.87$, $SD = 3.12$, $p < 0.001$). Also, Group2 outperformed Group1 ($p = 0.014$).

The three groups had the same initial knowledge level since there were no statistically significant differences in both pre-tests. Therefore, any differences found in the evaluation sheets can be attributed to the different teaching methods. Having that in mind, the results partially confirm H1, given that Group3 (a) was not outperformed by any other group in any case, (b) fared better than Group1 in all evaluation sheets but one, and (c) fared better than Group2 in two out of five evaluation sheets. The fact that Group3 outperformed the other groups in the delayed post-test, confirms H2. On the other hand, H3 has to be rejected because no statistically significant differences were noted in the post-misconceptions test.

Coming to the questionnaire, students' strong positive attitude towards the use of tablets was evident in most of their responses (Table 2), thus, H4 (students form positive views and attitudes for their teaching using tablets) was confirmed. Moreover, collaboration seems to have worked well ($M = 4.11$, $SD = .39$) and students acknowledged how important their partner was to the learning process ($M = 4.20$, $SD = .60$).

Table 2. Students' questionnaire.

Question	*M (SD)*
1. I collaborated with my fellow student nicely	4.11 (0.39)
2. I feel that working as a pair helped me to learn	4.20 (0.60)
3. I think that using tablets during the lesson is boring*	3.95 (0.76)
4. I think that using tablets during the lesson is an enjoyable activity	4.62 (0.50)
5. Working with tablets was fun	4.51 (0.42)
6. I enjoyed working with tablets	4.12 (0.76)
7. Working with tablets made me want to learn more about Geography	4.22 (0.40)
8. I was eager to conduct the project's lessons	4.05 (0.70)
9. I found the courses very interesting	4.07 (0.77)
10. I feel that I have learned nothing*	3.72 (0.48)
11. I believe that the lessons were like a game	4.20 (0.33)
12. Working with tablets was difficult*	4.41 (0.50)
13. I did not like the courses at all*	4.22 (0.60)
14. I would like to use tablets again in my teaching	4.44 (0.32)
15. It would be nice to use tablets in all lessons/courses	4.68 (0.28)

Note. * indicates a question for which its scoring was reversed

6 Discussion

The data analysis revealed that the performance of students who were taught with the use of tablets exceeded that of students who were taught conventionally (in all cases but one) and of students who were taught with the use of computers (in two out of five cases). These results are in agreement with previous studies, which compared conventional teaching with teaching using tablets [39]. Motivation for learning, students' active involvement in the learning processes when using tablets, and positive attitude towards their use are three factors that might have contributed to this outcome as suggested by others [40]. Indeed, students stated that they enjoyed working with tablets (see questions three through six) and that they felt motivated (see questions seven through nine). Also, an indication of students' positive attitude comes from questions thirteen through fifteen. The literature suggests that fun and enjoyment when using tablets act as facilitators of the learning process [41]. Indeed, students liked that they were having fun and, at the same time, they were learning (see questions five, six, ten, and eleven).

The animations, images, videos, interactive maps, and, in general, all of the micro-applications' multimedia features seem to have helped students to learn the relevant information. That is because the literature suggests that the visualization and interaction with the learning material that tablets and their applications offer, create a pleasant and attractive learning environment which, in turn, contributes to the learning outcomes [42, 43]. The second group of students also had access to rich audiovisual material since they used the interactive e-book. Given that both groups outperformed the first group in which only the textbooks were used, it is quite safe to assume that technology-enhanced teaching is expected to yield better learning outcomes compared to conventional teaching. On the other hand, and on the basis of the results, there was no clear advantage of tablets over computers, other than the lower cost, higher mobility, and their small form factor which result in easiness of use [15].

It should be noted that students in the experimental group were taught exclusively through tablets and without their teacher's assistance. In essence, they were forced to take control of their learning. On the basis of the results, it can be argued that the high degree of autonomy and control of the learning process can lead to good learning outcomes, as Falloon [44] suggested. At the same time, students worked in pairs, and this also contributed to the results. That is because tablets, due to their size and mobility, do not obstruct or interfere with face-to-face interactions, thus, allowing increased levels of interaction and cooperation between students [15, 18].

Students stated that working with tablets did not cause them any trouble ($M = 4.41$, $SD = 0.50$), confirming that they are compatible with students' ICT skills [45]. Although the use of tablets during teaching was something unprecedented for students, the smooth functioning of the classroom was not disturbed. Instead, a pleasant, fun, and collaborative environment was developed, which was verified by students' answers to the relevant questions (see Table 2, questions 1 and 2). This is somehow in contrast with the views of other researchers who suggested that the in-classroom use of tablets might be problematic since students can use them for non-educational purposes [22]. Presumably, the lessons' organization did not allow the occurrence of such phenomena.

In this study, students had their own tablets and they were allowed to take them home, thus, replacing their textbooks. It seems that this arrangement had a positive impact on the learning outcomes, confirming the views of other researchers who suggested that personal ownership leads to increased students' motivation, autonomy, and self-efficacy [22, 25, 29]. A probable explanation is that students were able to familiarize themselves with these devices and use them more effectively (in contrast to sporadic and time-limited in-classroom usage).

Coming to students' misconceptions, the results were inconclusive. In all groups an improvement was noted (see Table 1) but, still, about half of the answers in the post misconceptions test were wrong and this applied to all groups. In addition, no group was able to outperform the others. Misconceptions are persistent and hard to deal with [46]; it would be unrealistic to expect students to overcome all their misconceptions in the subjects they were taught, in the short period of time that the interventions lasted. Also, one has to keep in mind that the interventions were general purpose lessons and did not target students' misconceptions in specific.

6.1 Implications for Practice

The study's results have implications for educators as well as for software developers. An issue that had to be dealt at the early stages of the project was that of developing the micro-applications. Although Blippbuilder is not that difficult to learn and use, the development of the micro-applications by a non-specialist (the class's teacher), proved to be a quite time-consuming process. Moreover, the applications were far from reaching professional standards; it is quite probable that their flaws had a negative impact on the learning outcomes. Taking into consideration the project's results, one might argue that such an effort was not justified [47]. On the other hand, the idea of teachers being able to produce their own and diverse educational digital content is strongly supported. Therefore, we are in need of software tools that make the whole process much more efficient and appealing to non-experts [48].

The study's results can also lead to a number of suggestions to education administrators and policymakers. Students' positive attitude towards the use of tablets in teaching, together with the satisfactory learning outcomes (at least for the subjects that were examined in the present study), renders their educational exploitation an interesting idea. Also, time is a critical factor. Students need to have enough time at their disposal so as to use tablets at their own pace. Consequently, the primary school's curriculum and the hours allocated for subjects in which tablets are going to be used have to be reconsidered.

7 Conclusion

Despite the interesting results, the study is not without limitations. The sample (sixty-six students), though sufficient for statistical analysis, was relatively small; thus, the generalizability of the results is questionable. The number of teaching interventions was limited due to restrictions imposed by the schools. Other data collection tools, such as interviews and observations, would have allowed a more in-depth understanding of students' views regarding tablets.

Given that the present study presented the results of the project's first stage, the next stages will be conducted having larger sample sizes and a larger number of interventions. Further examination of students' misconceptions and if they can be eased with the use of tablets is also a very interesting topic. Finally, the use of other ICT tools (e.g., computers and smartphones) and other types of applications (e.g., multimedia and virtual reality) can provide useful information regarding the exact impact of tablets as an educational tool.

In any case, it can be concluded that tablets provide an interesting alternative method for teaching Geography to primary level. That is because students were more engaged in the learning process, increased levels of collaboration were noted, and the learning outcomes were good, compared to the other teaching methods. On the other hand, there is still a long way ahead before the full potential of tablets and their impact on pedagogy is realized.

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Mobile Technologies and Early Childhood Education

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Abstract. Few studies/reviews were conducted on mobile technologies and mobile learning for early childhood education, studies regarding young children aged up to 6 years old. This paper identifies and presents basic issues/topics regarding mobile technologies and early childhood education. It discusses theoretical issues and research results on the following areas: (a) mobile devices' usage by young children (frequency of use, preferred device, popular activities), (b) mobile technologies and early learning (e.g., effects on young children's learning of concepts, development of skills, motivation), (c) mobile educational applications that target preschool children (type of applications, design features, ease of use), (d) parents' and early childhood teachers' perceptions regarding mobile technologies and young children, and (e) ethical considerations in research with young children. Based on the findings, suggestions for future research are also given (e.g., teachers' acceptance of mobile learning, pedagogical support, cooperation between parents and early childhood teachers).

Keywords: Mobile technologies · Early childhood · Mobile learning · Mobile devices

1 Introduction

Mobile technologies, such as mobile phones, smart-phones, tablets (tablet PCs) and personal digital assistants (PDAs) have attracted the attention of the educators and researchers [1–4] to consider their pedagogical implications. Mobile devices are light enough, they might influence how learners learn, while there are multiple applications available to the users when connected using mobile devices. Examples of their uses include communication, casual entertainment (watching and sharing short movies, photo albums), navigation, capturing objects and events (usually as still images) and accessing web-based information as need arises. In the 2010s, most handheld devices are also equipped with Wi-Fi, Bluetooth, near field communication capabilities, as well as Global Positioning System (GPS) capabilities. The educational use of mobile technology is often referred to as mobile learning, with the focus on facilitating and extending the reach of the teaching and learning [3, 5, 6] such as knowledge construction, information collection and exchange, collaborative learning [7], independent learning [8] and lifelong learning [9].

Large scale research reviews and meta-analyses on mobile technologies and mobile learning [3, 10–13] found that higher education students were the most frequent

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research sample, followed by elementary school students and high school students. Additionally, while mobile learning was investigated in different contexts (formal and informal educational settings), informal learning was the preferred approach in most studies. A few studies have been published on mobile technologies and early childhood, in comparison to the other levels of education. For example, a few studies have been explicitly focused on examining the impact of touch screens on young children's learning [14, 15]. The aim of this paper was to identify and present basic issues regarding mobile technologies and early childhood education. The present study poses the following research questions:

1. RQ1. What are the issues studied in mobile technologies and early learning?
2. RQ2. What are the issues studied in mobile educational applications that target preschool children?

Through an advanced search by using Boolean logical operators (OR, AND), the search terms included the keywords "mobile technologies" or "mobile devices" or "mobile learning" or "mobile applications" with/and the keywords "early childhood" or "kindergarten" or "young children" or "preschool". The basic issues identified were then classified in the following five areas: (a) mobile devices' usage by young children, (b) mobile technologies and early learning, (c) mobile educational applications that target preschool children, (d) parents' and early childhood teachers' perceptions and (e) ethical considerations in research with young children. For presentation and discussion purposes, each of the above mentioned areas is discussed in a separate section. The terms "early childhood", "preschool" and "kindergarten" were used as synonymous, indicating the formal educational settings that attend, in most countries, children aged between 3 and 6 years old.

2 Mobile Devices' Usage by Young Children

Researchers [16] claim that the mobile/portable digital technology industry is increasingly targeting the younger members of society, and in many parts of the world touch screen technologies have become part of a common activity between adults and young children in the home environment [17]. Applications present a significant opportunity for out-of-school, informal learning when designed in educationally appropriate ways [18]. A recent study involving six European countries [19] reported that many young children have daily contact with a wide range of mobile digital devices/tools. For example, in the United Kingdom, in a survey of 100 parents, 73% of under-5 year old children were using a tablet or a laptop computer, compared to just 23% in 2012 [19].

Mobile touch screen devices are, with increasing tendency, very popular among young children compared to the desktop or laptop computer and this popularity is attributed to the following features - functions [20, 21]: portability, light weight, intuitive interface of the touch screen, no need for separate input devices (such as the keyboard or mouse), flexible design for easy installation (and running of applications), manageability for even very young children and autonomy. These devices include tablets, tablet devices of the type of iPad and smart phones. Study [22] reported that tablets were the preferred digital device for children aged 2–9 years, due to portability, ease of use and convenience. As in [23], in their research examining internet cognition in 4–5 years old children, researchers noted that children of preschool age have only ever experienced a world where internet accessibility through touch screen devices is a common, everyday resource. As many preschool children have not adequately developed their fine motor skills required to handle peripheral devices of conventional computers (such as the mouse), tablets are an attractive means of carrying out digital educational activities [24], since they only require the use of the finger.

In recent years, children in the USA have spent more time engaging in smart mobile devices than watching television [25]. Children use their mobile devices primarily for playing games (63%), followed by watching videos (43%) and far fewer (30%) are using the devices for educational content, such as reading [26]. In the United Kingdom, a survey found that 25% of children aged 0 to 2 years have their own tablet, this figure rising to 36% for children aged 3 to 5 years, while the time devoted to tablet use was found to be one hour per day [27]. A study in Singapore [28] found that tablets were the most popular portable device (used daily) for children under 7 years of age, while 3-year-olds spent most of their time on mobile phones. In a study with 6 year old children in Jordan [29], touch-screen tablets were used for different purposes with ‘playing games’ being the most common purpose, followed by watching YouTube. In addition, children were found to acquire most of the skills needed to use tablets, but still not in control in some cases.

3 Mobile Technologies and Early Learning

The fact that tablets are an incentive - motivation for children’s learning of concepts/skills has been reported in various studies [21, 30, 31]. For example, study [30] highlighted the effects of tablets on young children’s literacy skills: the use of tablets by 3–5-year-old children at home was positively linked to the knowledge of the sound of letters and the ability to write the name (skills that facilitate children’s future reading ability). Study [31] showed that the use of tablets by 4–5 year old children improved their readiness to acquire basic literacy concepts, including the most vulnerable children who have made progress. Young children, who have been creative in stories’ construction, have been strengthened in reading and writing areas. The ability to read, among 4-year-olds in Japan, was increased after exposure to e-books, but not after the same time of exposure to printed books [32].

Study [33] explored how the use of tablet applications affected children’s play and creativity, two important areas in early childhood. There were several potentially creative uses of tablets to improve the learning of children through play. However, this was based on application design, and some of the most popular applications were not age-appropriate and provided limited opportunities for play and creativity. Study [34] in Finland addressed issues related to mobile learning and pedagogy in early childhood education, and pointed to the development of mobile learning as a kind of play for young children (e.g., adapting mobile devices as natural and creative components of children’s play, understanding the effect of mobile devices on play).

A pilot project on the use of mobile devices in five kindergartens and their associated five elementary schools in North Ireland [35], evaluated the use of tablets for developing literacy and numbering skills. In general, there has been a positive impact on reading and writing, especially with the creation of digital books by children. Contrary to initial expectations, managers and teachers reported that the use of tablets in class enhanced children's communication skills: especially when children shared tablets, there was a high level of discussion. Mobile technology has been found to complement traditional teaching practices rather than replace them. Children's fine motor skills were improved when they practised letter formation on the screen, while the children who used the tablets had been motivated and viewed learning as play.

Study [36] implemented in a kindergarten class (4–6 year olds) a software application for counting and calculating with tablet computers and investigated the impact on children's mathematical concepts. The study used an experimental group (67 children) which received the intervention –daily use of tablet computers- and a control group (51 children) which was taught the same concepts in the traditional way. Pre- and post-tests were used for the concepts of comparison, classification, correspondence, seriation, structured counting and general knowledge of numbers. The results of the study support a positive correlation between children's early numeracy competence and the integration of tablet computers in teaching and learning numbers.

A systematic review [15] identified 19 studies reporting learning effects on children 2–5 years old. The number of children participating in experimental, quasi-experimental, or mixed-method studies was 862 and in descriptive or correlation studies 941. The majority of studies reported positive effects on literacy development, mathematics, science, problem-solving, and self-efficacy. Among the factors explaining observed effects were design features, the role of adults, and a similarity between applications and transfer context. Although drawing firm conclusions remains a challenge, this review forms a first step towards systematic research in the field and contributes to shaping directions for future research. There is lack of studies examining the impact on children's social and emotional development.

The introduction of tablets into the typical environment of the kindergarten has its opponents (e.g., [6, 37]). For example, they claim that technology can distract the class's 'fragile ecology' by opening up the possibilities for different types of learning, communication and interactions. They also warn that there are tensions when potential transformational technologies meet traditional educational practices. Moral panic can be caused by the difficulty of those involved in practices that are not familiar to many adults. These potential disruptions and trends in the classes are challenging, and teachers are the key persons to reduce their impact. As a result, early childhood teachers' perceptions on the use of tablets by young children are very important, while time is needed to identify appropriate applications that support specific learning objectives.

4 Educational Applications for Mobile Devices for Preschool Children

The use of software/applications for mobile devices has increased rapidly in popularity for preschool and young children. Study [38] showed that children aged 4 years and older can use the usual gestures required by mobile applications such as tap, drag-and-drop, slide, pinch, spread, spin/rotate and flick. Study [24] investigated the extent to which the self-reported educational applications with Greek content for smart mobile devices (Android operating system), intended for use by preschool children, have been designed according to appropriate developmental standards, in order to contribute to the cognitive development of children in the context of both formal and informal learning environments. They classified the educational applications in three non-exclusive categories: games applications (interactive features and educational content, either in the form of memory or puzzles), applications in the form of interactive e-books (combining text, narration, images, animations and other multimedia elements) and creative applications (including tools for designing, creating and developing skills). In terms of educational content, most applications focused on literacy (70%) and mathematics (30%), they tended to evaluate the pre-existing knowledge of the child (rather than teach new concepts) and were of behavioral type. Research results [24, 39] showed that the majority of the available applications were "drill and practice", based on low levels of thinking and skills. For example, e-book applications did not make full use of the capabilities of mobile handhelds and had decreased interactivity. The researchers [24] suggest the need for a comprehensive and up-to-date guide for evaluating mobile applications, an easy-to-use guide for parents, educators and software designers.

Study [40] examined the effects of a story-making application using forty-one 4 and 5 year old children in Spain. They noted that specific features and content of applications could influence the degree to which children's engagement with the learning task was of educational value. Study [41] conducted a survey in New Zealand with eighteen 5-year-old children who used tablets. He concluded that all applications should be evaluated for design and content prior to implementation in the classroom. He pointed out that, although new mobile devices have the potential to motivate children and create engagement with innovative learning opportunities, there is a need for appropriate applications for young children. For example, many of the free applications distract children's attention with advertisements, inappropriate feedback and un-justified noises.

5 Parents' and Early Childhood Teachers' Perceptions and Practices

It has been reported that mobile learning has been explored in different contexts (formal and informal educational environments), with informal learning (i.e. at home, museums, etc.) being the preferred approach followed in most studies. As a result, the views of both parents of young children and early childhood teachers are important - so far there is little empirical research evidence on this issue.

Study [42] in the USA, explored parents' (with children aged 3–18 years) perceptions on mobile learning and young children. Parents of children 3–5 years old, generally had positive attitudes, and seemed to prefer tablets as the main mobile device for their children (in comparison to mobile phones). They believed that mobile learning opens up new learning opportunities for their children, for example, it can make learning more fun, teach basic technological skills and promote curiosity. Mobile devices and applications were considered to have some educational content, to provide help in different cognitive areas and especially in mathematics. Another research study in Canada [43] found that parents of children aged 1–2 years give their children portable devices at increasingly younger ages. While parents expressed different opinions and concerns regarding the use of mobile technology by young children, this did not discourage them from using them with their children (in order to spend time with them, to take away the children's boredom and to provide them with some educational value). At the same time, the study revealed that while children were initially interested in the new mobile device, their interest was not necessarily maintained, and verbal interactions between parents and children were reduced during the use of mobile devices.

Study [44] in the USA explored early childhood teachers' perceptions and their practices, regarding the use of iPads in preschool classes. In general, there were positive views/perceptions on the contribution of tablets to children's learning, as well as on the increase of co-operation between home and preschool. The lack of technical support and the concerns about the appropriateness of technology with young children have been inhibiting factors. The researcher proposed structured support for the inclusion of tablets in the curriculum of the preschool.

Study [45] investigated the incorporation of iPads into the early childhood classroom through an exploratory teacher professional development initiative. Eighteen early childhood educators participated in a 6-month study targeting teacher professional development and pedagogical innovation. The results indicated that teachers had positive views and used the mobile technology in innovative ways (as an efficiency solution, as a bridge in virtual parent communication, and as curriculum enhancement). The researchers of this study argue that using the iPad in the curriculum, is the next area of professional growth for early childhood teachers.

Study [46], in the USA, looked at the informal feedback of young children who used tablets in the kindergarten classroom. In particular, 20 children 4–5 years old used tablets to practice phonological awareness and counting in mathematics, and 8 infants were taught the same skills without technological means. The children in the experimental group received guidance when using the tablets and they had improved on specific skills, in comparison to the control group children. Although the sample was small, the researchers suggested the use of tablets in specific cognitive areas of the curriculum to improve children's competencies. In study [29], the 6 years old children had, overall, reasonable knowledge of touch-screen tablets and their features, while they viewed touch-screen tablets as an entertaining tool more than as a learning tool. The children also expressed that their parents impose rules regarding tablet usage and they need help and guidance from their parents while using tablets.

Research regarding preschool children's views on mobile technology is in its infancy in the bibliography, but there are some studies for elementary school children. Indicatively, the research [47] in Taiwan, investigated the perceptions/attitudes and confidence of 9–12-year-old pupils towards mobile devices: in general, pupils had positive attitudes and high self-confidence in the use of mobile devices and the internet (via their mobile devices), with the existence of small gender differences.

More empirical data is needed on the views of parents (having young children) and early childhood teachers. For example, how parents perceive the use of portable devices by their preschool children? Parents' views are important because their engagement and support can normalize/influence any school constraints on the issue of educational technology and the introduction of mobile devices into the classroom. At the same time, as pointed out earlier, teachers' views are very important as these influence their practices and the effectiveness of any kind of technology in the kindergarten classroom.

6 Ethical Considerations in Research with Young Children

Ethical issues arise when investigating dependent, vulnerable members of society such as young children [48]. Gaining informed consent from research participants is widely regarded as central to ethical research practice and in institutional settings such as schools; access tends to be mediated by gatekeepers [49]. Within early childhood education settings, adult gatekeepers (teachers, managers etc.) frequently make decisions on behalf of the children in their care, including whether or not to provide access to researchers. It is common for gatekeepers to provide access, but then to delegate to children's parents the ultimate decision whether or not a child can participate. Study [50], conducting ethnographic video case studies with three-year-old children, discussed ethical considerations such as negotiating initial and ongoing consent, issues of anonymity when representing visual data, and keeping participants informed about research outcomes. Study [51] reported that when interviewing young children it is essential to examine the complex nature of confidentiality and consent. Participants need to feel free and safe to opt out whenever they wish to, in particular in the conduct of longitudinal research.

There has been a shift within childhood studies from viewing children as objects of research towards a view that stresses their competency, often as co-participants in the research process [49]. Researchers propose child friendly research designs, such as using visual methods, drawings and stories as research tools, or choosing group interviews. Participants' names can be changed in written accounts and erased from audio recordings, while digital technology enables on-screen faces to be obscured to protect identity. Researcher [50] reported that three-year-old children were asked to watch the videos during data collection and their views on their activities were often very clear. Researchers must be aware of ethical issues involved, and negotiate ethical frameworks for their research with young children.

Study [52] developed a holistic framework for ethical mobile learning that includes the following considerations that educators should be aware of. This includes: mobile learning as a learning practice; a positive ethic of responsibility for teachers and support personnel; a personal responsibility for children; agreed protocols; culturally appropriate practice; mobile etiquette; appropriate response training to unethical behavior for all gatekeepers. This framework could be adequately modified and it should taking into account in early childhood education research.

7 Discussion and Conclusions

This paper aimed to identify and present the basic issues regarding the field "mobile technologies and early childhood education". With regard to the first research question (What are the issues studied in mobile technologies and early learning?) a variety of different issues/topics were identified: the frequency of mobile devices' usage by young children; the type of mobile device children tend to prefer/use; the popular activities children carry out when using their mobile device; the effects of mobile devices' usage on children's learning of concepts/skills (e.g., investigating the effects on literacy and mathematical concepts/skills were predominant, while there was lack of investigating effects on emotional development); and the perceptions of parents'/teachers' regarding mobile technologies and young children. Very few studies mentioned ethical issues in research with young children (however, such issues are essential when conducting research with young children, research connected to mobile technologies). With regard to the second research question (What are the issues studied in mobile educational applications that target preschool children?) the issues/topics identified concerned the design features of mobile applications that target young children, the ease of use of applications by young children, and the types/categories of the so-called educational apps.

For discussion and presentation/communication purposes the different issues identified in this review, were classified/summarized under the following five areas (see Table 1): (a) mobile devices' usage by young children (frequency of mobile devices' usage, preferred type of device, popular activities carried out by children), (b) mobile technologies and early learning (effects of mobile technologies' usage on children's learning of concepts, development of skills, self-efficacy), (c) mobile educational applications that target preschool children (type/category of applications, design features, ease of use), (d) parents' and early childhood teachers' perceptions regarding mobile technologies and young children and (e) ethical considerations in research with young children.

The basic issues identified are not mutually exclusive and they are interrelated. For example, the design features of a mobile application, in combination with other factors (e.g., teachers' pedagogical practices) are expected to influence young children's learning and development of skills. The review findings can become a layover platform and guidance for researchers and educators. A limitation of this review is that the findings and conclusions are not intended to be exclusive. Since articles may take one year (or more) from submission to publication, the findings of this study may not reflect the most recent research issues/topics. Future studies are needed to expand the current findings.

Table 1. Summary of findings – basic issues/topics

Study	Devices	Ages	Findings
Mobile devices' usage by young children			
[19]	Various types	<8	Daily contact with a range of mobile devices
[27]	Tablet	3–5	Time devoted to tablet use was around one hour per day
[28]	Various types	<7	Tablets: the most popular mobile device
[22]	Various types	2–9	Tablets: the preferred mobile device
[26]	Various types	3–6	Use of mobile devices primarily for playing games, followed by watching videos, and far fewer for educational content
[29]	Tablets	6	Use of touch-screen tablets mainly for playing games, followed by watching YouTube
[23]		4–5	Internet experiences: only via touch screen devices
Mobile technologies and early learning			
[40]	Tablets	5,5	Learning of mathematical concepts (understanding numbers, counting)
[36]	Tablets	4–6	Impact on mathematical skills (numeracy competence, learning numbers)
[15]		2–5	Positive effects on: literacy development, mathematics, science, problem solving, self-efficacy
[46]	Tablets	4–5	Impact on phonological awareness, counting in mathematics
[35]	Tablets	3–7	Impact on reading, writing, fine-motor skills, communication, motivation
[30]	Tablets	3–5	Effects on literacy skills (sound of letters, write their name)
[31]	i-Pads	4–5	Improved readiness to acquire literacy concepts
[33]	Tablets		Effect on children's play and creativity
[32]	e-books	4	Improvement in reading ability
Educational applications for mobile devices for preschool children			
[40]	Tablets	4–5	Features and content of applications effect children's engagement with the learning task
[38]		>4	Children can use the usual gestures required by mobile applications (tap, drag-and-drop, slide, pinch, spread, spin/rotate and flick)
[24, 39]			The majority of the available applications were 'drill and practice', based on low levels of thinking and skills
[41]	Tablets	5	All applications should be evaluated for design and content prior to implementation
Parents' & Teachers' perceptions (on mobile technologies and early childhood)			
[43]		1–2	Parents: use mobile devices with young children, expressed some concerns
[42]		3–5	Parents' views: positive, they preferred tablets for their young children

(*continued*)

Table 1. (*continued*)

Study	Devices	Ages	Findings
[44]	i-Pads		Teachers' perceptions were positive, they identified some barriers (lack of support, appropriateness of apps)
[45]	i-Pads		Teachers' views were positive teachers' practices: innovative uses of mobile technology
Ethical considerations in research with young children			
[49–51]			Gaining informed consent, negotiating consent with children and adults (parents, teachers)
[52]			Development of a holistic framework for ethical mobile learning

8 Suggestions for Future Research

Mobile technology and mobile technology-based educational opportunities are constantly evolving [53]. There are indications that the use of (smart) mobile devices will continue to spread over the years, and this is a challenge for education: for teachers, researchers, and designers of mobile applications, about incorporating mobile technology for educational purposes. In general, the use of mobile devices for learning is a positive experience regardless of the type of the portable device. While portable learning is attractive to learners, the use of mobile technology does not necessarily mean effective learning.

Early years curricula provide no specific recommendations about which mobile applications best support learning, more likely due to the lack of empirical evidence and the relatively new release and diffusion of those technologies [14]. Schools make choices and uses of technology based on individual needs. Early guidance on how to use ICT and other technologies (including digital mobile technologies) responsibly and safely will help to equip children for the increasing contact and reliance they will have on these resources throughout their lives.

21st century children grow up in homes equipped with mobile devices and touch screens [54], but in the field of early childhood education there is still little empirical evidence in comparison to the other levels of education (elementary and higher education, in particular). Mobile technologies and mobile learning constitute aspects (subthemes) of the broad field of ICT, with the consequence of identifying similar issues for consideration. For example, indicative issues/topics for further investigation are: the effectiveness of using different types of portable devices in informal and formal educational contexts, the relationship between children's play and digital mobile technologies, as well as pedagogical issues (motivation for learning, appropriate feedback, etc.). Additionally, more studies are needed to investigate the effects of mobile applications on young children's learning and development across all areas of the early years foundation stage [55] (up to now, most studies focused on literacy and mathematics), and achieve continuity between learning at home and learning in formal settings. Particular attention should be given to the design and the content of educational mobile applications [39], in order to exploit the potential of mobile devices. It is note-worthy that the features of mobile devices are not sufficient conditions for positive learning effects.

A suggested direction is strengthening professional early childhood teacher-development programmes for mobile technologies integration. The involvement of University-level researchers as mentors or collaborators might be useful. In order to benefit from the use of mobile technology in formal educational environments, teachers should be aware of the various dimensions of mobile learning (how to use them, which pedagogical support/guidance to provide, etc.). An issue, for example, that has not been explored in sufficient scale, is the readiness and acceptance of mobile learning among early childhood teachers, as well as preschool educational institutions. At the same time, it is legitimate to inform the parents of young children to support their learning in the home environment and to cooperate with the school teachers. Parental involvement can influence any decisions undertaken at kindergarten, decisions related to mobile learning initiatives.

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Robotics and Coding in Primary Grades

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Abstract. Coding and robotics activities have traditionally been used with secondary students and often in after school programs. Seldom have these disciplines been a part of the mainstream curriculum and even more rare is having these be a part of the instructional programs for learners in the primary grades. Research conducted with primary education teachers has demonstrated the potential impact of including coding and robotics content integrated with traditional mathematics, science, social studies, and English language arts instruction. This research also suggests teacher preparation needs to begin early for STEM education.

Keywords: Robotics · Coding · Primary education · Elementary education · Active learning

1 Introduction

Student learning in school settings is conducted using a spectrum of pedagogies extending from passive, teacher-based, dialectic to active, student-centered, problem-based learning [1]. While some would argue that there is a place for all sorts of approaches, too often learning strategies have failed to engage students in effective ways. Use of active student instruction involving robotics, coding, and engineering problem solving holds significant promise of providing effective learning opportunities for all students and can simultaneously equip students with basic skills needed for 21st century success [2].

One issue that is of ongoing concern is the lack of balance in engineering and technical fields with respect to numbers of men and women entering these professions. There are significantly more men than women and this continues to be the case in spite of initiatives to encourage increased balance. Much of the prior effort has been focused on high school and middle school programs to expose and encourage women to consider technical fields [3]. One problem with these efforts is that identity with regard to confidence and interest in science, technology, engineering, and mathematics (STEM) is largely shaped and solidified in elementary or primary education [4]. Earlier interventions are needed if things are to change [5–7].

Robotics in schools has traditionally been an after school or extra-curricular activity [8–10]. As such, participants have been largely comprised of students who have some natural affinity for technical toys and are often made up of boys more than girls. The

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same is true of coding and other activities involving technology. Coding is a relatively new subject for schools to address and until recently was not something within easy reach of early learners or primary grade teachers. With the advent of block-based visual coding and low-cost easy-to-connect robots, that has changed [11]. Educational policy and decision makers are increasingly recognizing the importance of coding as a basic 21st century skill as well. Opportunities to enhance STEM content learning activities within standard school curriculum using robotics and coding activities are becoming more affordable and practical.

Infusing robotics and coding into mainstream classroom learning creates equal opportunities for students to gain experience and develop competencies, often stimulating interest where there was lack of recognition and awareness. All students are expected to participate in learning activities that are part of the curriculum. This is not about extra work or opportunities to do something different if work is completed early; this about instruction involving all of the students in a class. Girls as well as boys have opportunities to consider possibilities and move beyond innate interests that are largely shaped through societal norms and stereotypes. Students should not be pushed toward careers that are not of interest, but neither should they pass through formative years without exploring the full range of possibilities.

Hands-on activities can also enhance instruction of STEM content. Students put mathematics to use for an immediate purpose as they compute and control robotic movements. Science and inquiry take on meaning as understanding of simple machines and mechanisms is applied to robotics challenges. The too familiar questions of "Why do I need to know this?" or "When will I ever use this?" suddenly go away and learning is contextualized within real-world problem solving activities. Conceptually, the case for infusing robotics and coding into school curriculum is relatively easy to argue, but research is needed to inform teaching practice. Strategies for design of integrated instruction that adequately addresses learning standards and appropriate sequencing of content are needed. Guidance to determine a balance between perceptions of fun, play, and motivation to learn and having students achieve grade-appropriate learning guided by academic standards is also important.

2 Purpose of the Present Study

For the past six years, an undergraduate early childhood education course for students preparing to teach grades K-5 in U.S. schools has included a robotics unit to prepare prospective teachers for incorporating robot assembly and programming within mainstream classroom learning. Research has been conducted alongside this robotics unit to examine the impact on these future elementary teachers' STEM knowledge and interests. In numerous instances, they expressed doubt when the robotics unit was introduced and indicated they had never assembled something like this before, nor had they done any programming. Three weeks later they were excited to show and tell others what they had learned and accomplished as they participated in class poster presentations of lesson materials using robotics for elementary STEM education. Students exhibited high levels of enthusiasm during the experience.

Content developed for this undergraduate course was identified as valuable for practicing teachers as well. With new innovations in technology rapidly emerging and becoming available for use is schools, it is challenging for teachers to stay current with new instructional technologies. To address this concern, a professional development project for current teachers was developed and successfully proposed for funding by the U.S. Department of Education Mathematics and Science Partnerships (MSP). Activities developed in the early childhood education course were adapted and expanded to provide a robust experience for classroom elementary teachers over the two-year life of the project. Professional development workshops were conducted several times during the school year and during an intensive week-long summer experience.

The research reported here was conducted during this MSP professional development project. Enrolled teachers were invited to participate in a study to examine the impact of robotics workshop experiences on elementary engineering content knowledge and attitudes toward STEM. These teachers had no prior experience with robot assembly and programming and entered the project with varying degrees of uncertainty and anxiety. The following research questions guided the study:

(1) Is there any change in participants' engineering knowledge after participating in a robotics unit?
(2) Is there any change in participants' interests in STEM after participating in a robotics unit?

3 Methods

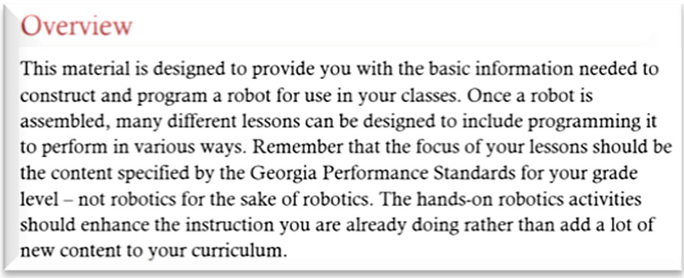
3.1 Research Design and Participants

A pretest-posttest single group design was used. Participants were recruited from a robotics professional development project offered for a school district in the southeastern United States. Twenty-four elementary teachers volunteered to participate. Prior to the first robotics workshop, an engineering knowledge assessment and a STEM interest survey were conducted. The pre-assessment scores and survey responses were compared to those collected after the workshops ended.

3.2 Robotics Unit

The workshop experiences examined by the research reported here consisted of a three-hour introductory workshop during the school year spring semester, two follow-up workshops during the school year spring semester, a week-long summer workshop, and a concluding workshop during the following school year fall semester. The initial workshops provided participants with individual hands-on experience reading instructions, constructing, and programming robots. Additional workshops incorporated group activities constructing and programming robots and developing instructional materials that incorporated educational robotics into STEM content instruction.

The workshops were largely adapted from the unit of instruction developed in the undergraduate course. As highlighted in the undergraduate course, the focus of robotics learning activities in these workshops for the current elementary teachers was to develop instructional materials to teach STEM content using robots rather than to design lessons to teach robotics (see Fig. 1). The total time involved with robotics construction and programming was similar and design of instruction was informed by those prior experiences. The workshop participants completed the pre-test instrument immediately at the beginning of the introductory workshop. Next each participant was provided with an entry-level robotics kit, tools for assembly, and a cable for downloading programming code.


Overview

This material is designed to provide you with the basic information needed to construct and program a robot for use in your classes. Once a robot is assembled, many different lessons can be designed to include programming it to perform in various ways. Remember that the focus of your lessons should be the content specified by the Georgia Performance Standards for your grade level – not robotics for the sake of robotics. The hands-on robotics activities should enhance the instruction you are already doing rather than add a lot of new content to your curriculum.

Fig. 1. A sample of some workshop material highlighting the purpose of lesson designs using robots.

Instructions for assembly of a robot were provided using printed directions with pictures and text and a completed robot that was shown and available for participants to examine up close. A verbal explanation was also provided including descriptions of key steps and points where mistakes might be commonly made. A demonstration of the programming software (see Fig. 2) and the procedure to download programs to the robot was also included.

The robot used for workshop activities was one procured from the Roborobo Company in South Korea (see Fig. 3). This particular model is relatively economical and provides all of the basic elements needed for educational robotics instruction in the primary grades. The assembly involves a variety of circuit boards, frames, and metal brackets assembled using machine screws. Two DC motors provide mobility, IR sensors and push buttons allow inputs, and colored LEDs and a buzzer provide outputs. Software is also provided and consists of block coding similar to Scratch. Downloading of programs is accomplished using a USB cable. It was important for each participant to have their own robot so that everyone had a fully engaged experience.

Participants were assigned a prescribed set of movements and actions for their robot to perform once it was assembled. Poster boards were laid out with geometric shapes to be followed, and a poster board was also provided with cardboard walls to serve as boundaries for the robot to travel within.

Guidance and support was provided throughout the introductory activity with the instructor and project team members circulating to assist and answer questions.

Fig. 2. A screenshot of the robot programming interface.

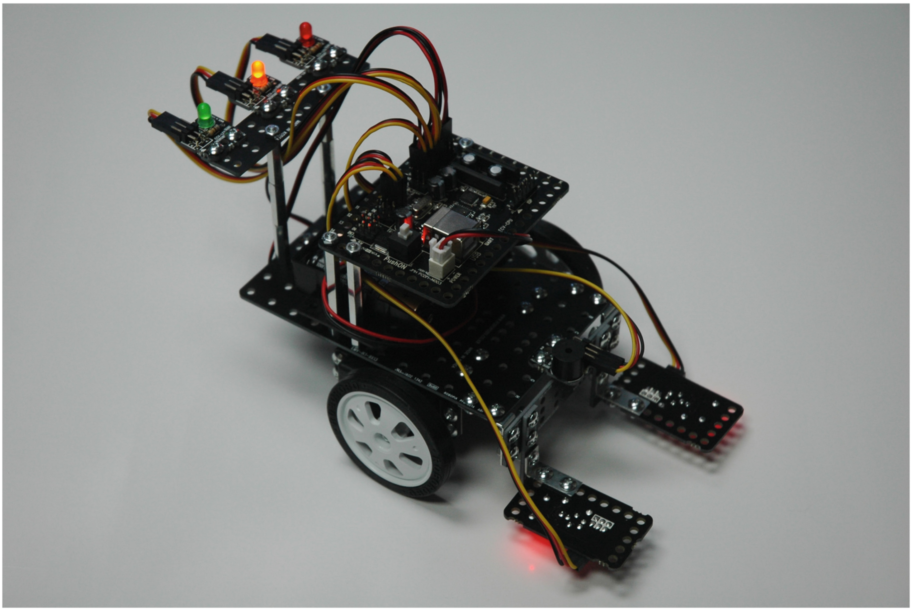


Fig. 3. Example of assembled robot.

Participants varied with regard to how much assistance was needed. The robots performed well and the coding activities covered basic elements needed to gain an understanding of logic control structures and programming strategies for robotics. During follow-up workshops the project participants further developed programming skills and constructed more complex robots using higher-level kit materials while working with a partner. Figure 4 illustrates how the complexity and difficulties of programming activities increased gradually.

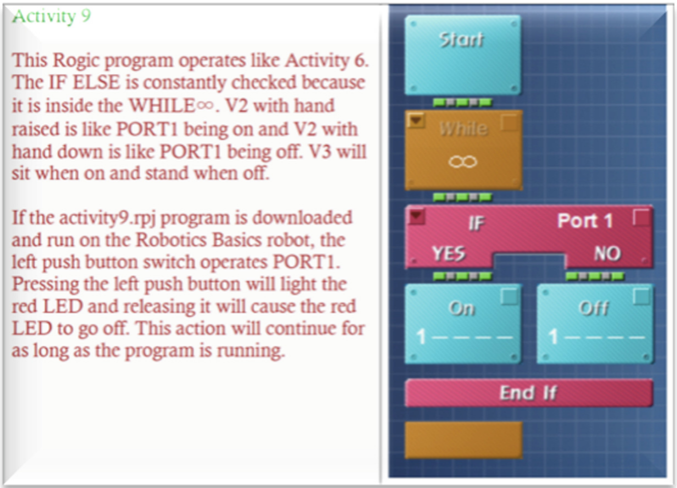


Fig. 4. A sample programming activity that built on earlier less complex activity.

During the summer a significant time was allocated for curriculum development and design of instructional plans and materials. The intent was to prepare teachers to be able to use robotics activities during the next school term to more effectively teach content they would already be teaching. Figure 5 shows a sample of instructional materials that guided teachers to address standards required within the content they were currently teaching.

The fall semester workshop allowed teachers to inquire about areas where challenges had arisen during classroom implementation. Group discussions and sharing of ideas and resources enabled teachers to resolve some of the issues that had become barriers to implementation.

Objectives

The following standards can be addressed by learning activities that include basic robot construction and programming. Numerous other standards can be addressed using learning activities with an assembled robot.

- MCC5.NBT.1 Recognize that in a multi-digit number, a digit in one place represents 10 times as much as it represents in the place to its right and 1/10 of what it represents in the place to its left.
- S5CS4. a. Observe and describe how parts influence one another in things with many parts.
- S5CS3. Students will use tools and instruments for observing, measuring, and manipulating objects in scientific activities.
- SS5H9 The student will trace important developments in America since 1975.
- SS5E1. f. Give examples of technological advancements and their impact on business productivity during the continuing development of the United States (such as the development of the personal computer and the internet).
- ELACC5RI7 Integration of Knowledge and Ideas: Draw on information from multiple print or digital sources, demonstrating the ability to locate an answer to a question quickly or to solve a problem efficiently.

Fig. 5. A list of standards that robotics learning activities might address.

3.3 Data Collection

Engineering knowledge was assessed using What is Engineering [12]. STEM interests were measured using the STEM Semantics Survey [13] in which participants' interests in the disciplines of science, technology, engineering, and mathematics were asked about. These instruments had been previously used in research conducted with future elementary teachers [14].

Table 1. Results of statistical tests.

Scale	Pre-survey (n = 24)		Post-survey (n = 24)				
	Results of paired samples t-test						
	M	*SD*	*M*	*SD*	*t*	*p*	*r*
Engineering knowledge and skills[a]	9.33	2.22	10.30	2.10	−2.45	0.02*	−0.22
Interest in mathematics[b]	5.59	1.44	5.31	1.30	1.33	0.20	0.11
Interest in engineering[b]	5.63	1.52	5.84	1.38	−1.12	0.27	−0.07
	Results of Wilcoxon signed rank test						
	M	*SD*	*M*	*SD*	*z*	*p*	*r*
Interest in science[b]	6.12	1.39	5.95	1.46	−1.76	0.08	0.60
Interest in technology[b]	6.43	0.79	6.24	1.02	−1.16	0.24	0.10
Interest in STEM career[b]	5.88	1.23	5.83	1.34	−0.45	0.65	0.02

* $P < 0.05$

[a] Possible range of Engineering Knowledge and Skills: 0–14

[b] Possible range of Interest in Science, Mathematics, Engineering, Technology, and STEM career: 1–7

Administration of the instruments was done using hard copies and hand-written responses. Sufficient time was set aside for administration such that participants were not rushed. Once participants completed the instruments, they moved on to some guided work with the robotics kits, but adequate time was allowed for all to provide thoughtful answers for instrument items.

4 Results and Discussion

To test whether the differences between the pre- and post-survey of all variables were normally distributed, we conducted a Kolmogorov-Smirnov test. Interest in science ($p = 0.00$), interest in technology ($p = 0.005$), and interest in STEM career ($p = 0.00$) did not meet the normality assumption, so a Wilcoxon Signed-Rank test was conducted to compare the pre-survey and post-survey responses for those variables. The pre- and post-survey of other variables were analyzed using paired-samples t-tests. The analyses show that participants' engineering knowledge and skills ($t = -2.45$, $p = 0.02$, $r = -0.22$) significantly increased after attending the workshop. The result is presented in Table 1.

5 Conclusions

Previous research with undergraduate students who participated in a four-week robotics unit, part of an elementary STEM course emphasizing hands-on active learning, has demonstrated that both content knowledge and interest were significantly impacted [3]. These undergraduate students often expressed doubts about how well they were prepared to teach STEM content and were reluctant to initiate hands-on activities with technical materials unless encouraged to do so by required exercises. Once they took steps to try, they found success and gained confidence. Support was provided to guide and encourage success, but the research in these situations demonstrated impact on both content knowledge and interest.

The present study findings suggest that the impact of learning experiences with a robotics unit is different for practicing teachers in primary grades as compared to those taking undergraduate teacher preparation courses. It is important to note that the instructor of the undergraduate course and the practicing teacher workshops was the same person. In prior research with future elementary teachers, participants' STEM interests increased, particularly engineering and science, after the robotics unit [3]. However, the present study with current elementary teachers, there was no significant change in their STEM interests.

Further research would be needed to determine whether interest in STEM was different between undergraduate students preparing to be teachers and practicing teachers. The previous research and the study reported here only examine changes within the homogeneous groups. It stands to reason, however, that practicing teachers might already hold higher levels of interest in STEM as a result of their experiences in classroom instruction and the social and cultural influences exerted on schools.

For over a decade the national narrative in the US has expressed concerns about student performance on international examinations such as the Programme for International Student Assessment (PISA) and other measures of STEM performance in schools. Prominent studies have been conducted by organizations like the National Academy of Engineering to examine how STEM content is being addressed in schools [15]. Organizations like the National Science Foundation have provided significant funding for research to assess the effectiveness of STEM instruction and politicians have promoted coding in schools beginning in the primary grades [2, 16].

Teachers are often called upon to address societal and workplace concerns, regardless of whether they have been prepared to do so or not. When they are already employed and in situations where administrators and others are asking them to address particular issues in the classroom, measures of interest in those areas is likely to be elevated and remain so. They need to be prepared to teach all of their assigned content, even where they lack relevant expertise, but they might already have interest in those areas, either due to perceived student needs or societal demands.

An alternative explanation for the findings in this study is that the participating teachers were not exposed to elementary STEM instruction, robotics, and coding during their teacher preparation programs and thus entered the teaching profession without having measurable interest in these areas. Furthermore, pressures to focus on established content standards and student achievement in traditional areas might have caused them to be resistant to change in interest even though changes in knowledge and skills occurred.

This explanation seems less plausible than the prior. Undergraduate students preparing to be teachers consistently showed an increase in interests related to STEM as a result of participating in robotics learning activities. It would be logical for practicing teachers to exhibit similar changes if they did not already hold interests in these areas.

Considering teachers' interests influence their methods and foci of teaching, especially at the elementary level, to promote STEM teaching, STEM interests are an important issue [17, 18] and further research to discern whether practicing teachers do in fact have healthy levels of interest in this area should be conducted. These interests also need to be cultivated from pre-service teacher years [3]. Teachers need to be prepared to include STEM content instruction using hands-on activities with their students and they also need to model appropriate interest in this area so that students become excited about the possibilities and opportunities afforded.

University faculty who are involved in preparation of future primary grades teachers as well as professional development of practicing teachers can enhance the learning opportunities for children to gain essential skills by including robotics and coding instruction in teacher preparation programs of study. While coding might be viewed as an additional content area in an already crowded curriculum, hands-on robotics activities that address learning goals in STEM content areas can actually provide enhanced student motivation and achievement. Coding is also being identified as an essential 21st century skill and students who begin learning to code at an early age will have significant advantages as they seek to be successful in future work and life endeavors.

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Enhancing Junior High School Students' Epistemological Beliefs About Models in Science

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Abstract. The adoption of models and modelling practices in science education is a widely accepted method. However, students' beliefs about models deviate from the scientifically acceptable ones. This research aims to enhance students' epistemological beliefs regarding science models by the use of a model based, inquiry Teaching Learning Sequence as an intervention method. The latter contains modelling processes and practices that incorporate Information and Communication Technologies such as applets, the Cabri Geometry II software and Phet applications. Their main common feature is the adoption of the ray model which is used for the interpretation and the prediction of light phenomena. The virtual experiments are complementary to the real ones, providing realistic representation, increased interactivity and measurability. The results indicate an increase in students' performance in their epistemological beliefs regarding the nature, purpose, multiplicity, and change of scientific models. In addition, it is this study's intention to unveil the criteria by which students distinguish and categorize images representing obvious models from non-obvious ones, as well as from non-science representations.

Keywords: Models science TLS

1 Introduction

Numerous researches point out that the use of models and modelling practices contribute to the increase of students' epistemological awareness regarding the nature, purpose, multiplicity and change of models [6, 9, 10]. A precondition for achieving the above objectives is the development of modelling skills, which in turn presupposes the development of a proper framework for the support of these activities [7]. However, it is found that students' perceptions of scientific models differ significantly from scientifically acceptable ones [14]. In this paper, we attempt to enhance the epistemological beliefs of high school students about the nature, purpose, multiplicity and change of models before and after the implementation of a properly designed Teaching Learning Sequence (TLS) integrating Information and Communication Technologies (ICT). We theorize that the latter can actually improve students' epistemological beliefs and help them distinguish science models illustrated from images portraying non-science models e.g. technological devices. Within this context, the present study

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focuses on the application of a research-base TLS in which 8th grade students are explicitly engaged in and reflected on modelling pedagogies related to the ray model in optics, the main research questions are:

- What are the changes on students' epistemological beliefs about the nature, purposes, multiplicity and change of models after their engagement with modelling pedagogies embedded in an inquiry oriented model-based TLS in the field of optics, integrating ICT technology?
- What are the changes on student's ability to recognize and distinguish images depicting non-models from images representing obvious and non-obvious models after their engagement with modelling pedagogies embedded in an inquiry oriented model-based TLS in the field of optics, integrating ICT technology?

2 Method

2.1 The Teaching Learning Sequence

The TLS used in this research is a product of modification and evolution of an earlier TLS developed in the framework of a European program on the visual properties of materials [4, 13]. The original TLS was modified in order to become aligned with Greek curriculum and redesigned to provide an appropriate supportive framework for developing students' epistemological beliefs about models by incorporating a plethora of modelling practices [10].

In specific, the customized TLS includes expressive modelling practices in which students construct and use their own models. In addition, it consists of exploratory modelling practices in which students use pre existing models. Furthermore, inquiry modelling practices are adopted i.e. models are used to make predictions which later on will be submitted to tests for validation. Finally, cyclic modelling is also incorporated as a continuous process of designing, testing and revising the models created. It is worth mentioning that the notion of a model is introduced in an explicit way at the TLS. At the same time, the revised TLS includes a number of metacognitive episodes aimed at reflecting and providing feedback to students.

The TLS also incorporates Information and Communication Technologies (ICT) in order to strengthen the supportive framework of modelling activities. ICT's are extensively used in the TLS. To begin with, a Flash application is used to provide the means to bridge reality with the ray model adopted throughout the TLS. Additionally, Cabri Geometry II software is also used. This software allows the transfer of real experiment photos into the virtual world acting as a bridge between the real world and the virtual one. The real world experiment image can be simulated in a more abstract manner through simulation. The software is also equipped with proper virtual tools that allow students to make their own measurements. This process allows students to visualize, manipulate and familiarize with the ray model and gradually accept it as a representation of the true phenomena (Fig. 1).

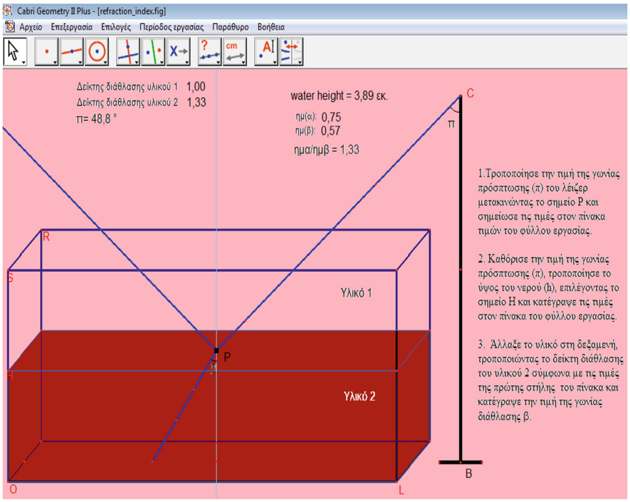

Fig. 1. Simulated virtual world and measurement tools.

For the purposes of this investigation, the TLS is further modified in terms of both expression of questions and their content. With regard to the second mater, the basic conversion includes adding more reflection questions and integrating the "Bending Light" application from Phet Website, supported by the University of Colorado, USA [1]. The integration of this application into the TLS provides a user friendly, virtual interacting environment in which light is represented as a ray. The "Bending Light" application allows also for the visualization simultaneous of the incident, reflected and refracted light beam as well as the manipulation and progressive change of their angle in real time. Furthermore, it provides the necessary virtual tools for the measurements of the previous mentioned angles (Fig. 2).

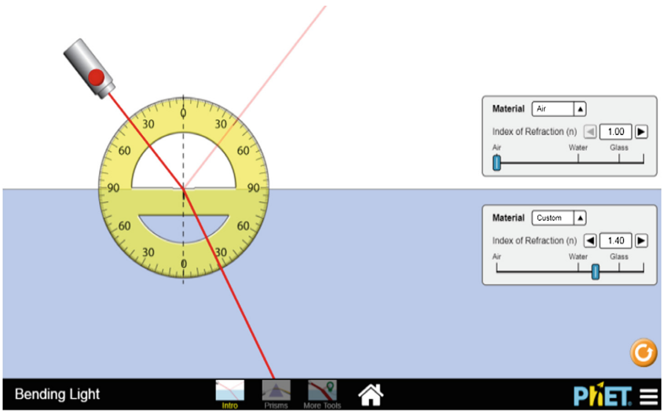

Fig. 2. Bending light Phet application environment.

2.2 Participants

The sample consists of 60 junior high school students (8th grade) of a public school in the prefecture of Thessaloniki, who participated in the research during the school year 2016–2017. The school is located in a rural area and the socio-economic level of the students' families considered low to average. Physics including optics is part of the compulsory curriculum. During the implementation of the TLS, students worked in small groups. The intervention lasted 8 weeks in a total of 12 teaching hours

2.3 Instrumentation

In order to investigate their epistemological beliefs about models two questionnaires were introduced both before and after the implementation of the TLS. The first one is closed-ended questionnaire which consists of 18 images in total. Below each image students choose between "yes" and "no" as to whether the image depicted represents a model or not. The pictures of the questionnaire are categorized into three clusters. The first cluster consists of images that do not represent a model. The second one comprises of images that represent models which are easily accepted as ones while the third cluster consists of images that although they represent models, they are hardly accepted as ones by the students. Such classifications is based on students' responses during earlier investigations [3, 15] which showed that there are many interpretations of a model by students such as human models of clothing, role models, exact copies in scale (cluster 1). Other students' replies refer to models as images, drawings, engineering plans and maps (cluster 2) or regard models as an idea, a representation, a mathematical or theoretical model (cluster 3). Accordingly, the first questionnaire was classified into three clusters as shown in Table 1.

Table 1. Image classification in clusters.

Cluster 1	Cluster 3	Cluster 3
Camera	Globe	Graph
F1 race car	Human skeleton 3D representation	An equation
TV personalities	Cell 3D representation	Water molecules simulation
TV set	Earth's interior sketch	Blueprints
Cell phone	Sketch of plant's parts	Chemical compound simulation
House	Functional miniature of a car	Photosynthesis sketch

The second questionnaire is an open-ended one and it consists of seven epistemological questions regarding the nature, purpose, multiplicity and change of a model. It was developed by Soulios [9] and it is based on questionnaires from earlier surveys [2, 3]. The classification of students' beliefs is based on the hierarchical three-level classification framework, developed in previous investigations [2, 3, 16]. Students' beliefs are classified into three levels. The first one includes answers that deviate from the scientifically acceptable ones whereas the second level consists of intuitive answers that tend to approach the scientifically correct ones without being totally identical. Third level's answers are those that are identical with the scientific ones.

After the completion of both questionnaires, a subset of 22 students was randomly selected to participate in semi-structured informal interviews. These interviews are more like discussions between the researcher and one student each time and they are conducted on familiar and student friendly environment. The questions asked are based on their answers in the previous mentioned written questionnaires. Taking into consideration that models are vague and abstract entities for students, these interviews provide a unique tool of investigating student's thoughts. Therefore, the researcher encouraged students to justify their answers on the images of the first questionnaire and to elaborate their answers in the second questionnaire regarding the nature, purpose, multiplicity and change of a model. The interviews provided invaluable information regarding students' criteria as to why an image should be or not considered as a model. The interviews were conducted before the implementation of the TLS and after its completion.

3 Results

The results of the open-ended questionnaire regarding the epistemological beliefs of students are presented on Table 2. Students who failed to provide any answer are classified in the first column as No Answer (NA). Based on the results, students' level of epistemological awareness is increased in all aspects of models after the implementation of the TLS.

Table 2. Percentage of students' answers per image cluster.

	Before TLS (%)				After TLS (%)			
Level of epistemological beliefs	NA	1	2	3	NA	1	2	3
Nature	10,0	83,3	6,7	0,0	1,7	66,7	23,3	8,3
Purpose	8,3	71,7	20,0	0,0	1,7	50,0	48,3	0,0
Multiplicity	8,3	23,3	63,3	5,0	3,3	13,3	65,0	18,3
Change	16,7	3,3	75,0	5,0	3,3	10,0	65,0	21,7

The results of the paired sample T-test regarding the same questionnaire are presented in Table 3. To avoid bias in our results, all T-tests in this research have been performed using 1000 samples Bias Corrected and Accelerated (BCa) with 95% confidence intervals.

Table 3. Paired sample T-test on epistemological beliefs.

Paired sample T-test	Model			
	Nature	Purpose	Multiplicity	Change
T-statistic	−4,50**	−5,33**	−3,24**	−2,40*
Statistical significance p	.000	.000	.002	.020

*p < .05
**p < .001

According to the results, students' epistemological beliefs show statistically significant improvement in all aspects of models such as its nature, purpose, multiplicity and change, after the implementation of the TLS

We then proceed to the analysis of students' answers on the first questionnaire. Table 4 presents the average value of positive responses per image cluster, i.e. the percentage of students who consider that the images depicted represent a model, as well as their change.

Table 4. Average percentage of positive answers and change per image cluster.

	Before TLS (%)	After TLS (%)	Change (%)
Image cluster 1	58,89	38,98	-19,91
Image cluster 2	51,94	62,15	10,21
Image cluster 3	55,28	58,47	3,19

According to Table 4 the percentage of positive answers regarding the first image cluster is significantly decreased. At the same time, a notable increase of positive answers regarding the second image cluster is recorded which means that after the completion of the TLS students do realize that the images of cluster 2 represent models. Regarding the answers on the third image cluster, only a slight increase is documented which implies that students' perceptions do not change. This indicates that students have more difficulty in accepting cluster 3 images as science models.

The paired sample T-test results conducted on the abovementioned answers are presented on Table 5. According to them, statistically significant changes on students' beliefs emerge in cluster 1 and cluster

Table 5. Paired sample T-test per image cluster.

Paired sample T-test	Cluster 1	Cluster 2	Cluster 3
T-statistic	4,07**	−2,34*	0,00
Statistical significance p	.000	.023	1,000

*p < .05
**p < .001

4 Discussion

Based on students' answers in both written questionnaires as well as their interviews it is evident that after the TLS is concluded students' epistemological beliefs regarding science models are promoted in all aspects such as their nature, purpose, multiplicity and change. In addition, having concluded the TLS students are capable of rejecting images representing non-models, like the ones in cluster 1. For example the cell phone image presents a significant drop in student's answers which means that after the intervention students discard cell phones as models. This implies that after the implementation of the present TLS an important number of students change their original beliefs and they no longer recognize the images of cluster 1 as models. Furthermore, the use of ICTs improves students' acceptance of cluster 2 images as true science models. For example the average percentage of students that regard the three dimensional representation of human skeleton as a model is increased by 23%. As far as the images of cluster 3 are concerned, it appears that the TLS has a limited affect on students' conceptions of a model. Students have difficulties in comprehending and accepting the abstract representations of cluster 3 images as true science models. This implies that the model based TLS applied and the modelling activities incorporated, improve students' understanding about science models. On the other hand, no statistically important improvement on students' answers is acknowledged in cluster 3 images representing elaborate science models.

Moreover, students' transcribed interview analysis unveils certain criteria (axes) by which the former recognize and sort images into obvious science models, non-obvious ones and non science models. To begin with, the first axis deals with a model's purpose meaning that students categorize images into models according to what models are supposed to do. For some students, who mistakenly accept images of cluster 1 as true science models, models are technological devices which help us in our everyday life. Based on this belief it comes as no surprise why images like a cell phone, a camera or a TV set are models are considered as models. On the other hand, the same axis is used by students in order to justify their answers in cluster 2 and 3 images. According to these students, a science model is not used for our everyday life rather than to help us understand and interpret physical phenomena or to teach us. Moreover, some students explicitly stress that models are simulation of reality rather than the reality itself.

Another criterion as to why some images are considered to represent science models whereas others don't is the nature of a model (axis 2). According to some students, technological devices are considered to be science models because they are constructed by scientists and not from "ordinary" people. In other words, every electronic device is a model. On contrary, students who reject human technological devices of cluster 1 as models claim that a model is a theory, an idea or even a process which helps us discovery something else. This kind of reasoning focuses on the nature of a model and forms axis 2.

Finally, a third criterion is identified as combination of the first two axes and the notion of evolution meaning that students attribute to models the ability to change. On the one hand, students who mistakenly consider technological devices as models propose that upgrades can be made to "models". On the other hand, students who reject the abovementioned images as models support that true models can change if they contrast with experiments and reality or perhaps when a new, more suitable theory is established.

Overall the light ray model, which is explicitly introduced throughout the TLS, is capitalized by the various digital tools. The latter actively scaffold the visualization and manipulation of the ray model making it in a way concrete. We consider that such a contribution by the integrated ICT is crucial for enhancing the construction of a conceptual bridge between real world experiments and virtual ones by engaging students in model based practices [5, 8]. As a result, students benefit from the teaching intervention and their epistemological beliefs are improved. The results are in accordance with previous research studies that reported on the effectiveness of virtual laboratories as educational environments [11, 12]. Therefore, we deduct that the implementation of the present TLS which explicitly introduces the optical ray model to students in order to use, describe, interpret and predict light related phenomena, increases their epistemological awareness of models.

In retrospect, further investigation is needed into highlighting students' criteria as to whether an image represents a model or not. Additional data are required in order to investigate students' persistence on considering electronic devices as models and rejecting abstract images of true models even after the TLS intervention.

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Science Teachers' Practices Following Professional Development

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Abstract. Our research focuses on Greek science teachers' practices in terms of TPACK before and after being trained by B' level professional development program. Our goal is to present the outcomes of B' level and show whether science teachers change their teaching through this program. Our analyzed data have been collected via class observations and respective interviews after the completion of the program. Class observations helped to check if science teachers were actually implementing ICT in their teaching and observe the way they accomplish this implementation and interviews aimed to provide insights in science teachers' practices and clarify any misunderstandings created during class observations. Class observations indicated that although science teachers were trained to use a plethora of tools and software, they usually use only those that they find more suitable for their teaching and design complete scenarios using these tools. Moreover, even though science teachers know how to design a teaching scenario and acknowledge its importance, prefer not to have a written scenario.

Keywords: ICT · Technological Pedagogical Content Knowledge · Professional development · Practices

1 Introduction

Although there is a plethora of professional development programs on ICT integration running worldwide, studies have shown that teachers tend to use ICT more peripherally preserving their existing teaching practices (usually the traditional teaching model) and use ICT tools to search the internet for material in order to produce notes or worksheets or for extra information [10, 11]. Reference [6] note that teachers usually use technology in order to deliver content instead of using it to effect meaningful changes in students outcomes.

Moreover, existing research data show that conventional seminars usually focus on developing technology skills (general or educational software operation) and thus cannot help teachers understand how to support specific pedagogical approaches in order to raise knowledge in each curriculum [12, 23]. It has also become clear through studies that ICT integration in class in a more explorative, participatory and

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co-operative way often requires changes in traditional forms of teaching and apparently teachers need to be trained to do so by professional development programs [10, 16].

ICT integration in class requires complex teacher's knowledge. In particular, this knowledge has three parameters which need to be combined: content, pedagogical theory and technology. Reference [15] introduced a widely used model that shows the interrelations between these three parameters - components. Technological Pedagogical Content Knowledge (known as TPACK) model shows the interrelation between Content Knowledge, Pedagogical Knowledge and Technological Knowledge which-when it comes to the matter of ICT integration in teaching - is constant and helps science teachers to evolve. This previously mentioned interrelation shapes complex knowledge that is Pedagogical Content Knowledge (PCK) which includes strategies and representations suitable for teaching, Technological Content Knowledge (TCK) which includes knowledge of the software and their applicability and the most complex Technological Pedagogical Content Knowledge (TPACK) which includes the know how to integrate ICT in teaching so as to support planning and implementation of specific teaching strategies.

In Greece science teachers are being trained on ICT integration in class by a national Professional Development program, known as B' level. The design of B' level–although it isn't clearly mentioned in its curriculum - is based on the previously mentioned model of Technological Pedagogical Content Knowledge (TPACK). B' level focuses on designing teaching integrating ICT and follows the principle that a more accessible way to support ICT integration is to provide teachers with technology-infused lesson plans that guide the preparation and delivery of a lesson [9] or train teachers to prepare by themselves their lesson plan - scenario. In a scenario, a teacher notes the way he/she intends to use ICT [14] and at the same time writes down the activities and the corresponding worksheets and the goals that every one of them is aiming at. All the above help teachers move away from their usual way of integrating ICT usually described as their status-quo where teachers use ICT only for the delivery of content [6].

Worldwide, although in previous decays most researchers tried to investigate teachers' attitudes and beliefs regarding ICT integration in class and less directed their research to teachers' ICT practices in science teaching [18], nowadays, researchers like Reference [1] are interested in studying teachers' practices.

In the present study, our goal is to locate any modifications in science teachers' practices concerning ICT integration because of the B' level professional development (PD) program which is detailed below. Therefore, our study focuses on TPACK-P, a TPACK edition that refers to the knowledge framework that science teachers develop from and for their practical teaching integrating ICT [22].

2 The B' Level Professional Development Program on ICT and Science Teaching

In Greece teacher's PD in the pedagogical exploitation of ICT, is part of a nationwide programme of in-service primary and secondary teachers including science teachers, in the use and implementation of ICT that is being coordinated by the "Diophantus"

Computer Technology Institute and the Greek Ministry of Education under a scientific committee [3].

The non-obligatory programme, called B-Level (we shall use this term hereafter for the sake of brevity), followed the A-Level PD program and has been in progress since 2006. Teachers form groups of 10–12 in special learning centers across the country and are educated by 1–2 specialized teachers-trainers. B' level includes a General Pedagogical part, a Specialization in Teaching Science ICT part and classroom practicum in the trainees' classrooms.

As mentioned before, the program was designed according to the principles of TPACK model introduced by Reference [15]. The General Pedagogical part of B' level matches the pedagogical content of TPACK, learning of software and its possibilities is linked to the technological content and classroom practices combine all TPACK's components. B' level, on purpose doesn't evolve the content (the subject to be taught) knowledge component as this is a task to be completed by universities. B' level focuses on making science teachers understand how ICT can support the design and implementation of specific pedagogic strategies in the classroom e.g. promoting explorative, inquiry-based and co-operative learning using ICT and finally on practicing what science teachers were taught to do. Hence, TPACK-P model (mentioned before) is more suitable to its curriculum considering that it deals mostly with practices.

Furthermore, it is important to note that the material of B' level and its applications were based on the components of the TPACK model in an indirect way and without direct reference to them [16, 19]. The scientific committee suggested not to do so, because it would potentially cause misunderstandings to the trainees.

3 Method

3.1 Sample

It is common known that most teachers don't want to be observed by an external observer during their teaching. It causes them insecurity and anxiety as they tend to link class observations to their evaluation [21]. In our research, it was important to make clear to science teachers and their school directors as well that fulfilling the instruments wasn't any kind of evaluation. So during the research, 11 trained by B' level science teachers agreed and were chosen of a larger pool to be observed while teaching and integrating ICT.

Class observations were held in different parts of Greece (all in different schools). Due to transfer and time restrictions, every observation was limited in 1 didactic hour. All science teachers were experienced (from 10 to 30 years of work experience) and were trained by B' level during the previous PD program.

3.2 Research Tools

This study is a sub part of a wider study that included multiple research methods. In this paper, only class observations and the respective interviews will be analyzed. The first author is the observer and interviewer who took detailed notes during observation and interviews. In previous studies our goal was to write down teachers' attitudes and beliefs about ICT integration [19, 20] but in this paper we follow the need to see what teachers actually do and not just what they think or say they do.

For the class observations, a special record tool – rubric was developed that included: school framework and ICT equipment that could be used, teaching design, teaching phases, teacher's and students' role, interaction between teacher and students, worksheets, value added by ICT integration and general estimation (positive and negative parts of teaching). All the above mentioned were designed according to TPACK model and every parameter was linked to TPACK components.

Before the design, other research rubrics [7, 8, 13] were analyzed and tried to be linked to TPACK model. Our rubric was developed in relation to the rubrics designed by Reference [13], and included a plethora of questions either closed questions in 5-point Likert Scale (like "Did the science teacher use internet applications during teaching?" and "yes or no" questions (like "Did the software used showed a phenomenon that could not be shown in a live experiment?") or open questions. In every question, the observer could note the observed facts in order to prove her choice. In case of an existing written teaching scenario or a worksheet, the observer asked the teachers to share it with her in order to have a more detailed and spherical view of the teaching.

Later, the rubric was piloted and readjusted according to the pilots' feedback. Then, it was sent to a panel of experts (3 phd teachers and 2 school consultants) who evaluated the links between parameters observed and TPACK model and suggested more parameters so as to have a more clear view of teachers' practices concerning ICT integration.

Semi-structured interviews were also necessary. Interviews were conducted after the observations and lasted about 20 min each. The interviews were recorded (under the permission of the interviewers), were coded into protocols and then were analyzed qualitatively. The semi-structured interview that followed class observations aimed to provide the opportunity for in-depth probing into participants' practices and clarify any misunderstandings created during the class observations. The interviews were conducted according to a special record tool-rubric as well that linked teachers' answers to TPACK. For example, while teachers were asked to mention the value added by integrating ICT in class, the rubric let us find out if all TPACK's components were interacting.

It is important to note that, following B' level's policy, - although all research was designed upon TPACK model - the actual term wasn't mentioned to the participants so as not to cause any confusions.

3.3 Data Analysis

The analysis of the instruments (for the class observations and interviews) started right after the rubrics were filled in. The analysis was completed individually i.e. every class observation rubric was analyzed combined to its matching interview rubric. The two rubrics were merged into one so as to have a full image of every teacher's practice. A special image with all the links between answers and TPACK model for every teacher was created, so eleven characteristic images were created in total. Figure 1 depicts the linking between class observation and interview data and TPACK model components while the analysis was in progress (due to data plethora, it is not possible to insert the full (final) image).

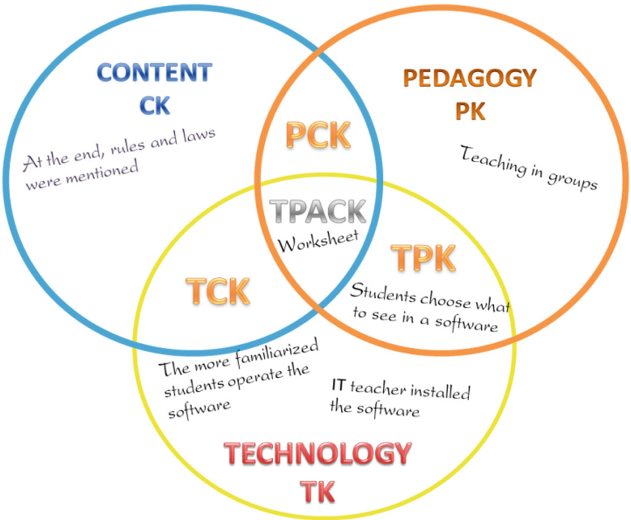

Fig. 1. Class observation and interview data linked to TPACK model for teacher no1.

As shown in Fig. 1, TPACK model has seven different unique or interrelated components (CK, TK, PK, PCK, TCK, TPK and TPACK). In a class, during teaching using ICT it is difficult to observe the unique components (CK, TK, PK) as they tend to interrelate automatically without any effort from the teacher e.g. the teacher knows how to use a software (TK) but at the same time decides to use it in a specific way (PK) so as to help students understand a phenomenon (CK). As the observer asked science teachers to observe their teaching while they were integrating ICT, the technological (TK) parameter was practically obligatory. Thus, the two rubrics depicted mostly three out of seven TPACK interrelated parameters (TK, TPK and TPACK) as they were designed- targeted to show.

4 Results

As mentioned before, 11 class observations and 11 following interviews were held. The results were categorized according to TPACK's parameters mentioned above.

For the sake of brevity in our data analysis and the results we merged PK with PCK and TK with TPK.

4.1 Participants' Pedagogical and Pedagogical Content Knowledge

At the beginning of the data analysis, we dealt with the way the teacher handled his class and which teaching method he/she chose to use. Most science teachers (ten out of eleven) chose to work in groups and only one didn't form groups and promoted individual work. The first ten science teachers formed groups from 2–5 students depending on the class arrangement. The groups were already formed before the observed teaching and in their interviews science teachers mentioned working in groups every time they integrate ICT in their teaching.

Regarding the students' role, science teachers admitted rarely giving the possibility and the flexibility to their students to participate in the scenario forming. A teacher said: "*When I go to my class I already have a scenario which I progressively reveal to my students, so they cannot easily express their opinion on it".*

On the other hand, science teachers asked their students to be more active and express their hypothesis on the subject to be taught. At the end of teaching they were called to compare their hypothesis to their conclusions and see whether they assumed right or wrong.

It is encouraging though that only one science teacher chose to teach completely traditionally. Commenting on their teaching method, all science teachers admitted to keep traditional elements in a smaller or bigger level. One teacher noted: *"It needs a lot of effort to change something so deep. I was taught traditionally and keep teaching this way but I try to reduce it. I think someday I will manage to do so."*

4.2 Participants' Technological and Technological Content Knowledge

Starting with the less complex component (TK) and the equipment used, we noted that only one out of eleven schools didn't have an IT lab. Moreover, only, two teachers weren't as confident to install a software although they were trained to do so by B' level. However, no class observation took place in a lab. Teaching was accomplished either using a projector either an interactive board. In their interviews, science teachers mentioned that IT labs in their schools are usually used only by IT teachers, therefore they turn to the alternatives of projectors and interactive boards. This data is compatible to other studies that argue limitation in accessing technological equipment as an important external factor for ICT integration [4, 6].

Regarding tools and software used, eight out of eleven teachers used tools that were taught through B' level program since they were more familiar with their usage. The rest three science teachers used applets that identified through personal web search. During the interview, one of three noted: "*This was the goal of B' level, to make us search, evaluate and use new tools. If we rest assured and use only those that B' level gave us, in a few years those will be outmoded*". Besides, all science teachers mentioned knowing how to search the internet for new software. Six out of eleven actually moved on to the usage of new software while a few mentioned that they are unable to do so because most software is using English and their level in foreign languages isn't satisfying. One specifically said: "*I loved Phet applets and I was so pleased to find them in Greek but this is an exception. A very small percentage of technological tools are translated into Greek and thus I think most science teachers of my age (the younger* *less) are disappointed and discouraged to use a new software. So we stay at what B' level gave us…".*

Several teachers activated their students' participation using technology. So, in three classes, the two most familiarized to technology students took charge of the equipment. In other two classes, in every activity, another group of students was chosen to operate the software. This way the teacher's role was more coordinating and the students' role was getting more energetic. The observer observed the students a different mood and will to act, while in the previous teaching where the teacher was in charge, the students seemed numb.

In other classes, the science teacher had the control of the equipment. Teaching was teacher dominated and students were answering questions after observing what the teacher wanted them to observe. It is notable that in the interviews, all science teachers stated that they would prefer a more active participation of their students and this is shown from a teacher's words: *"In an ideal world, I would like all my students to be ready to use whichever software without losing time in explaining how, every group to have a pc and me… just sit and observe. But this is the real world and I still teach traditionally although I know it's not the best for me or my students."*

4.3 Participants' Technological Pedagogical Content Knowledge

Moving towards the integration of technology, pedagogy and content, we found out that all observed science teachers followed a scenario during their teaching. However, only three of them had a written scenario in their hands which was handed to the researcher during the interview. All three scenarios included scientific and social objectives, distinctive phases and links of every activity to the objectives. Those three teachers who had a written scenario, stated that B' level program helped them gain a data base with scenarios, activities and worksheets either designed by them or designed by their colleagues. They mentioned that those written scenarios were chosen from their data bases and used them creatively, e.g. *"I usually choose a scenario from my scenario bank but I never use it as it is. I always readjust it to my students' needs and level".*

All the rest science teachers mentioned having a similar data base but using it seldom. In their interviews, all eleven science teachers (including the previous mentioned three) noted that they always have a scenario in their mind but they find it meaningless to write it down. For example: *"I have a 16 year- experience in classrooms and I think I have never followed the same path in class even though I teach the same content. I could not have a written scenario because every time, I think my students direct my teaching and not vice versa*". These science teachers prefer keeping only notes because a full scenario is time consuming. Besides, as a teacher mentioned during the interview "*While I teach, I have not even a spare second to check the scenario…just little glances to my notes so as to remember the structure".*

As regards the worksheets, seven out of eleven teachers distributed one to their students. The worksheets promoted group work as they should be filled out by the student - secretary of the group after the group observed the demonstrated software, discussed and came to a conclusion. In the interviews, the teachers mentioned that in B' level they learned how to design worksheets but they needed to adapt them to match the actual teaching conditions. Characteristically, a teacher noted: *"In my computer, I have a big folder full of worksheets that I cannot use as they are. I have to change them and adjust to the usual condition meaning not having a lab. But I hope I will use them one day as it is. Dum spiro spero".*

More specifically the used worksheets included observation, recording questions and estimation - conclusive questions. In most of teaching observed (six out of seven that had a worksheet), after the completion of every task, every group announced its answers and all the groups had the chance to compare results and discuss.

It is worth mentioning a different approach by one teacher who chose to let the groups fulfill all the worksheet and then proceed to the announcements and discussion. She stood up for her choice during the interview by saying: *"I think that this way I can minimize my role. I try to let my students act as a group and I just help them overcome any technical obstacles."* The interviewer asked the reason why she thinks that could not do the same thing and have similar results if working activity by activity. He/she mentioned that the psychological factor affects students' behavior and efficiency. He/she specifically mentioned: "*My worksheet has four activities. If I stop their thinking at the end of every activity, I intervene at least 4 times. If I let them fulfill all the activities, I intervene less. I let them feel free to act and more responsible".*

Previously, we mentioned that observed science teachers rarely gave the opportunity to their students to participate in the scenario forming. As it comes to the matter of activities forming, the data analysis showed something different. Science teachers had already designed the activities but in seven cases accepted in one or another way to let their students intervene. Thus, the students proposed to change some parameters in the software so as to see what will happen. The observed science teachers accepted to divert out of their initial scenario and activities and let their students feel more active. During interviews, most of science teachers, even those that didn't let their students intervene, admitted that they would like to not be so strictly attached to the scenario but the lack of time didn't allow them to.

5 Conclusions

As it comes to the matter of ICT integration via activities, worksheets and scenarios, the level of their integration managed to be impressively raised by the trained participants.

It is really encouraging that science teachers were trained by B' level to design worksheets and they keep on doing so after its completion. Reference [5] noted that well-designed questions in worksheets can draw students' interest while paired with the appropriate teaching method and that worksheets have a variety of functions in different contexts. The participants teachers seem to recognize the advantages of using or developing a worksheet and try to apply its usage in different situations. Most of them used written worksheets including several activities drawn from a personal data bank developed creatively by themselves or their colleagues.

It is memorable though that, although science teachers were trained by B' level not only to design and use worksheets but to develop whole scenarios as well, in their actual teaching the majority of the participants kept this scenario in their mind and only few had it written. This is a matter that needs further research.

Hence, the interrelation between technology, pedagogy and content (meaning all TPACK' s components) is obvious and through B' level program, is gaining ground over the traditional approaches that don't promote the interaction between all TPACK's components. Participants showed ability to link all TPACK's components, design and implement teaching where technology, pedagogy and content interact in order to achieve their goals. However, it is difficult to diminish traditional teaching as the observed teachers admitted and this depends on several external factors, notably the limited access to digital equipment. Reference [2] mention the same as in their research ICT was mostly used to support teacher lectures and student's homework.

We consider that B' level helped Greek science teachers to implement ICT in their everyday teaching in a more organized way using scenarios, worksheets and activities. In contrast to a traditional lesson plan, similarly to Reference [17] research, teachers seem to prefer a well-designed "activity" idea that encourages learning as a process linked to the curriculum context.

More class observations are scheduled in the immediate future in order to compare newly trained by B' level teachers' everyday practices and the practices of teachers who have been trained in previous B' level programs.

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Digital Technologies and Instructional Design

Simulation of Interference and Diffraction Based on Quantum Electrodynamics

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Abstract. In this work, we present a set of simulations designed to study interference and diffraction optical phenomena. The simulations are based on Feynman's Quantum Electrodynamics description of such phenomena. The first simulation aims at demonstrating that although photons can take any trajectory starting from the source to the detector, the net effect is that light travels in a straight line. By allowing the photons to pass only through a slit then one can observe the diffraction effects. By varying the parameters of the simulation, students can make a detailed study of the diffraction phenomena. The phenomena of interference can also be studied with the second simulation by introducing more slits to the path of the photons. Since there are many experimental settings and different outcomes, one can compare the results from the present simulations based on the general method of Feynman with the approximate results of the traditional theory of diffraction.

Keywords: QED · Interference · Diffraction grating · Light

1 Introduction

Whether light comprises of particles or it is a wave has caused a lot of controversy. Newton's position that light has particulate nature was refuted by the Huygens theory of diffraction and interference phenomena and afterwards by Maxwell who established the electromagnetic waves. To explain the interaction of light with matter, Planck and Einstein have resurfaced the notion of photons, i.e. the particles of light. But still such particulate theory could not explain the phenomena of diffraction and interference [1].

Heisenberg's uncertainty principle, a basic quantum principle, which applies to particles can only partially explain why in the diffraction phenomena light does not seem to follow geometric optics. On the other hand, the duality of particle-wave due to de Broglie could not be considered a truly quantum explanation of diffraction phenomena since there is still need to resort on Huygens theory.

The solution to the above difficulties, with great consequences in the way we see light interaction phenomena, was given by Richard Feynman in 1941 with the theory of Quantum Electrodynamics (QED). Feynman's solution follows a different theoretic approach, which has come to be known as path integral formulation [2].

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Feynman, in addition to being a great scientist was also a great teacher. He could explain in simple terms, all the new ideas of Physics and the workings of the world in a series of lectures delivered to a general audience. These lectures are the contents of the book "QED The Strange Theory of Light and Matter" [3]. Feynman's solution is based on the following two rules of how to calculate the probability of detecting photons, which start from the source and arrive at the detector:

1st Rule: To calculate the probability of occurrence of an event we draw arrows. "The probability of the occurrence of a particular event is equal to the length of the arrow squared."
2nd Rule: "When an event can be achieved in many alternative ways, then we draw an arrow for each event and sum all the possible arrows."

The purpose of the present work is to produce a set of simulation based on QED. Teachers introduced simulations for instruction well before the introduction of computers in teaching. Simulations were deemed necessary to allow students to access by analogy, real situations which are either dangerous, microscopic, have expansive time and length scale, not easy to control, or happen rarely. The recreation of situations with the above characteristics was and is still based on hands-on materials [4]. The availability of computers in schools led to the introduction of computer simulations with much new functionality and therefore freeing simulation from specific materials and designs and thus deeming them relatively easy to: change through programming, introduce multiple presentations, and adapt to the students' needs.

Simulations' utility in teaching has been reviewed by examining published work. Scalise et al. [5] found that simulations augment students' academic outcomes, but also skills related to formulating research questions, conducting experiments, analyzing simulation data and arriving at valid conclusions. A literature review on the effects of computer simulations on learning from 2001 to 2010 revealed that computer simulations augment traditional science classrooms by providing useful visualizations and "virtual laboratories" [6]. Furthermore, Sokolowski and Rackley [7] noted that using simulations augments the teaching of limits and makes possible for students to immerse in the virtual model of the physical world and in the inquiry processes.

One can find long lists of potential advantages of computer simulations to allow students access real situations and there is no need to repeat them in here [8–11]. Suffice to point out some additional features which the present simulations include by design and will be useful in the context of discovery learning. First, the underlying theory used for light or material particles propagation is at present the most general one thus enabling the design and implementation of any related experiment. Second, the geometry can be easily defined, lengths can vary from μm to m, the wavelength can be set to any desired value, there are multiple representations which can be switched on or off, selected results can be stored and retrieved to compare different cases, and quantitative results can be obtained.

The present simulations will allow either high school or university students, to apply the scientific method to the problem of light propagation through a grating, find out the counter intuitive way of light propagation and derive important conclusions. Based on the above simple and general rules they can reproduce without any additional assumptions known results derived normally from Huygens theory by invoking suitable approximations. In addition, the simulations can be used to experiment in new nontraditional situations and arrive to valid conclusions.

2 Method

To provide the environment for the application of the scientific method on the rather difficult topic of the application of QED to optical phenomena, it is necessary to design and develop simulations with appropriate functionalities. The clarity and the simplicity of the layout is also one important aspect of the design. It is well known that simulations offer many attractive features while studying physics phenomena, like: it is easy to change the time and length scale [8], they can run on many handheld devices, can be used for distance education, allow students to discover knowledge through exploration [12], and can be paused to allow students to assess and record data [10].

The first question that we will answer is how using Feynman's rules, which allow any path to photons, light seems to travel in a straight line when traversing free space or a homogeneous medium. The latter fact is part of our common experience, as we cannot see behind objects, we observe the formation of shadow, and see well defined edges of objects. We start with this case, which is very simple, to present many features of the designed simulation interface.

Photons starting from the source at point A to reach the detector at B have many allowed trajectories, either straight or not. To each photon reaching the detector an arrow is assigned. All the arrows have the same length but the direction can be different. The direction of the arrow does not represent the direction that the photon has travelled. We can imagine that as the photon travels the arrow changes direction with the angle being proportionally related to the frequency of the photon and the time of flight.

Let us suppose the we want to calculate the probability of a photon starting from the source at A to arrive at the detector in position B, with no obstacle in between, Fig. 1. Each route corresponds to an event and an arrow is assigned to it. This arrow of constant length, when the particle arrives at the detector, has an angle which is proportional to the frequency of the photon or particle and the time of flight. The arrows of the different paths, as they arrive at the detector, are depicted one next to the other on a horizontal line. The photon can take any route, but all routes do not contribute equally to the detection probability. More specifically, only the photons which travel close to the line connecting the source to the detector have arrows pointing almost to the same direction and thus the sum has a large length and therefore a high probability to be detected. This can be seen in the line where the arrows are displayed one next to the other in Fig. 1. Specifically, in Fig. 1 we consider only paths close to the straight line connecting the source (A) to the detector (B). Therefore, the sum of all these arrows is a vector with large length. To visualize this, we have added a plot of the arrows, the resulting vector (blue arrow) and a blue square. The area of the blue square with sides equal to the length of the resultant vector is the intensity detected by the detector. All the above means that those photons having paths close to the line AB have a great contribution to the measured light intensity.

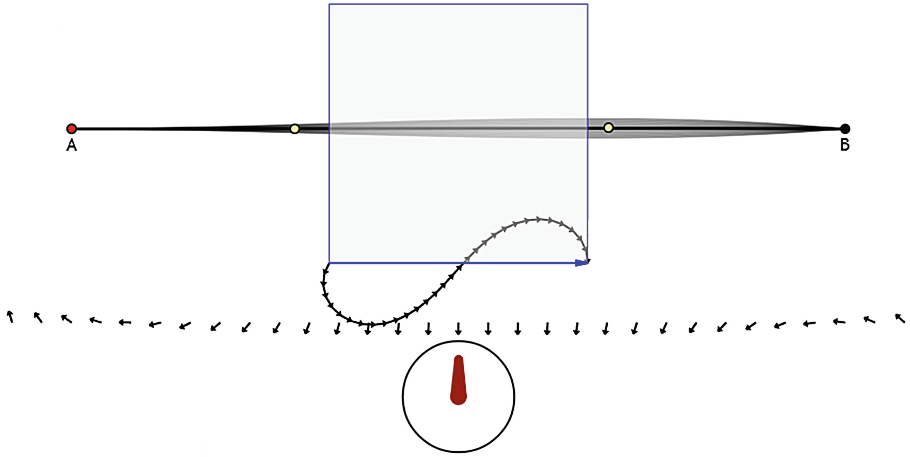

Fig. 1. Paths close to the line connecting the source (A) and the detector (B). The line with the arrows shows one arrow for each path. All these arrows are summed graphically and the resultant vector is plotted in blue. The blue square has an area which is proportional to the detected intensity of light. (Color figure online)

An example of the contribution to the intensity of paths away from the line that connects the source (A) and the detector (B) is given in Fig. 2. The curved path was set using the two points denoted with small empty circles. In the example the points have moved away from the straight line connecting the source and the detector. These, can be freely moved interactively and a spline curve is drawn to connect the source and the detector. The simulation produces paths which deviate from the spline curve and pass from A and B. One can notice that the arrows are pointing at different directions. Even arrows of neighbor paths have significantly different directions. The summation of these arrows leads to a vector of almost zero length, which along with the blue square is a big dot in the middle of Fig. 2. The webpage containing the simulation for the above experiments can be found in http://seilias.gr/QED/files/en/lightPath.html.

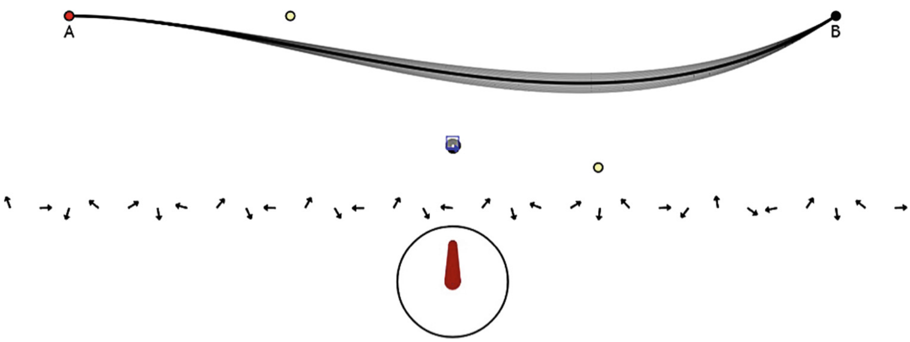

Fig. 2. Paths close to a curve which is away from the line connecting the source (A) to the detector (B). The student can arbitrarily produce and experiment with such curves by moving the two small empty circles.

As we have seen above, by letting photons exploit all the available paths close to the straight line connecting the source to the detector, light seems to travel in a straight line. Restricting all the other paths will not make much of a difference to the result. The question arises, as to what would happen, if we restrict some of the paths that contribute significantly to the signal of the detector. Would that mean that the signal will be smaller? There are many ways to restrict such paths. Here we will resort on a model which although is simple it can encompass many phenomena and the only input that we must consider is its simple geometry. This can be achieved because of the generality of the two basic rules of QED. All these ingredients make it possible to even study the transition from one traditional diffraction setting, to another. The geometry is specified by the presence of an opaque plate which can have one or more openings (slits) and is placed between the source and the detector (Fig. 3). It is possible to define the number of openings, their width and distance. Also, the distance of the source from the plate and the detector from the plate can be chosen by moving their representation on the screen. The simulation with all the above functionalities can be found at the link: http://www.seilias.gr/QED/files/en/diffractionFeynman.html.

If we place a grating with one wide slit (Fig. 3) then many paths cannot be realized because of the opacity of the grating. Only paths that connect the source to the detector and pass through the slit are allowed. As before, to determine the probability of detecting a photon we sum the arrows of all possible paths from the source to the detector. We can observe that depending on the position (Fig. 4) of the detector we get different sum for the arrows, i.e. different probabilities. The largest probability corresponds to the photons following paths close to the straight line that connects the source to the detector and passes through the slit.

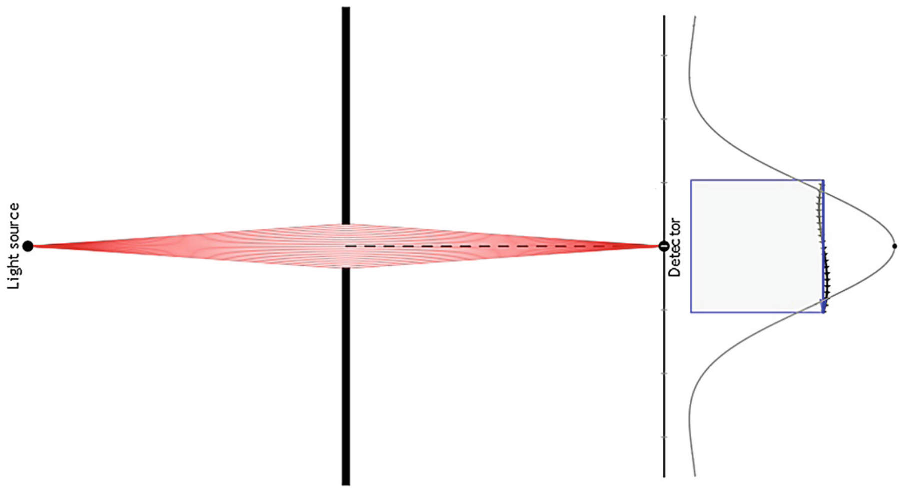

Fig. 3. As photons pass through the slit of relative large width the probability for the detector to detect them is large since their path is close to the straight line that connects the source to the detector and passes through the slit.

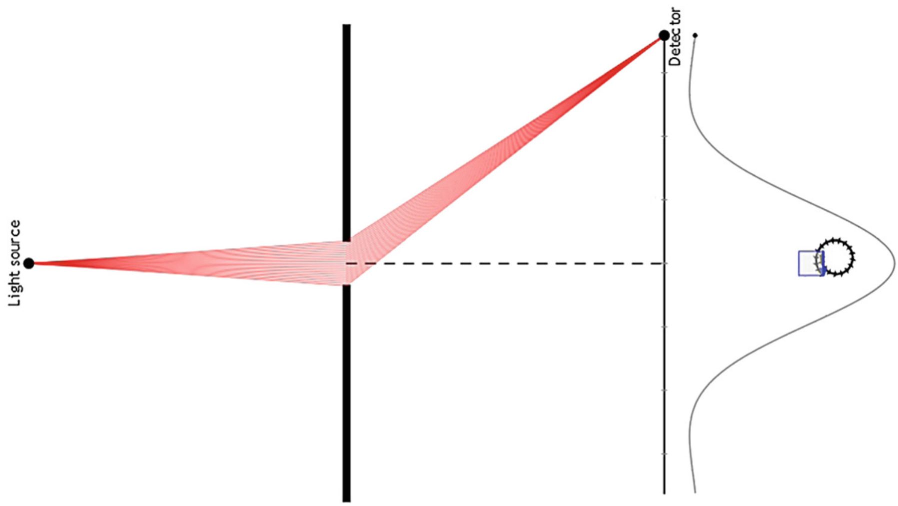

Fig. 4. When photons pass through a relative wide slit the probability to detect them far from the center of the screen is small as it corresponds to paths far from the straight line.

If the slit opening is set to be extremely small (this can easily be set in the simulation through a slider), then there are not many alternative routes and the times of travel do not differ a lot, resulting that no matter where we place the detector we will always find a finite small and almost the same probability to detect a photon. Two instances of the above are displayed in Figs. 5 and 6.

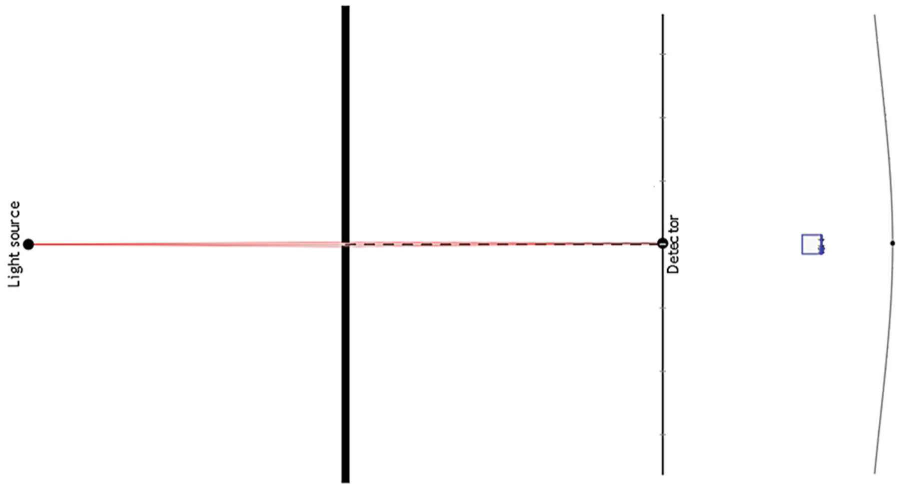

Fig. 5. When the slit width is relatively very small then around each path away from the straight line, there are so few paths available and the arrows are having almost the same direction therefore inducing a small but almost constant probability.

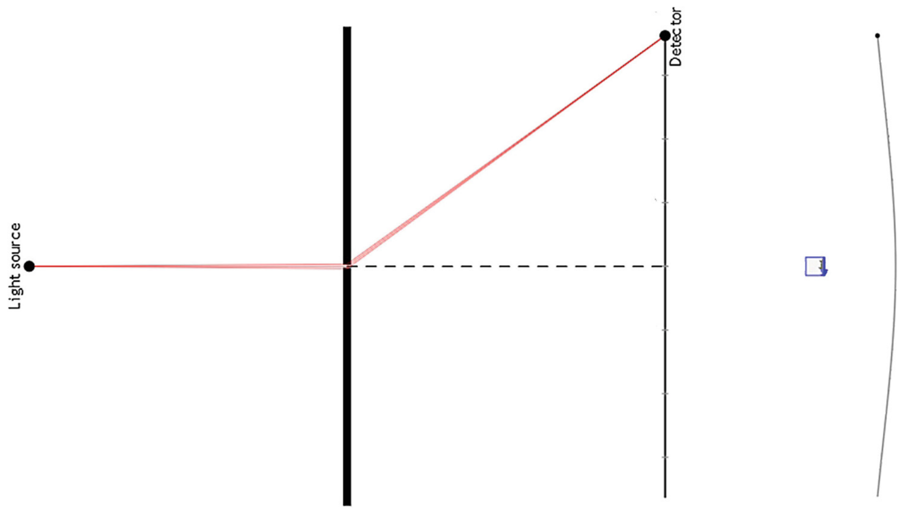

Fig. 6. For paths, away from the straight line, since the slit is relatively small all the available paths have similar distances resulting to a small but finite probability for detection of the photons independent of the position of the detector.

To study Fraunhofer diffraction we performed a simulation with one slit (N = 1), slit width α = 3.5 μm, distance of the opaque plate and the detector = 5 m and the wavelength λ = 700 nm (Fig. 7). We can observe that the first minimum occurs when x = 1 m. With this datum, we can check the related formula sin $\theta = \lambda/\alpha$ [13].

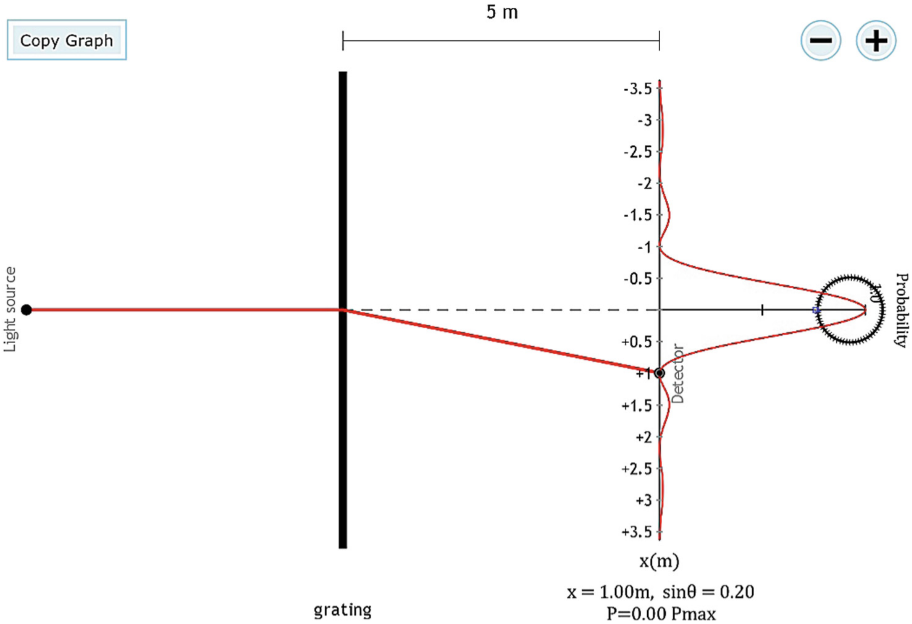

Fig. 7. Fraunhofer diffraction from a thin slit.

It is possible to change the length scale of the simulation by pressing the (+) or (−) buttons. This way, we can transit from the far field diffraction to the near field one. When we approach the distance between the source and the detector of 500 μm we have noticeable differences. Therefore, this is a signal that we are moving from the distance where the Fraunhofer approximation is valid to the Fresnel one. One of the key points of introducing the present simulation is that we can study a whole range of possible geometries and situations without making any approximations, which traditionally are necessary to study some specific cases (Fig. 8) and without complicated mathematics.

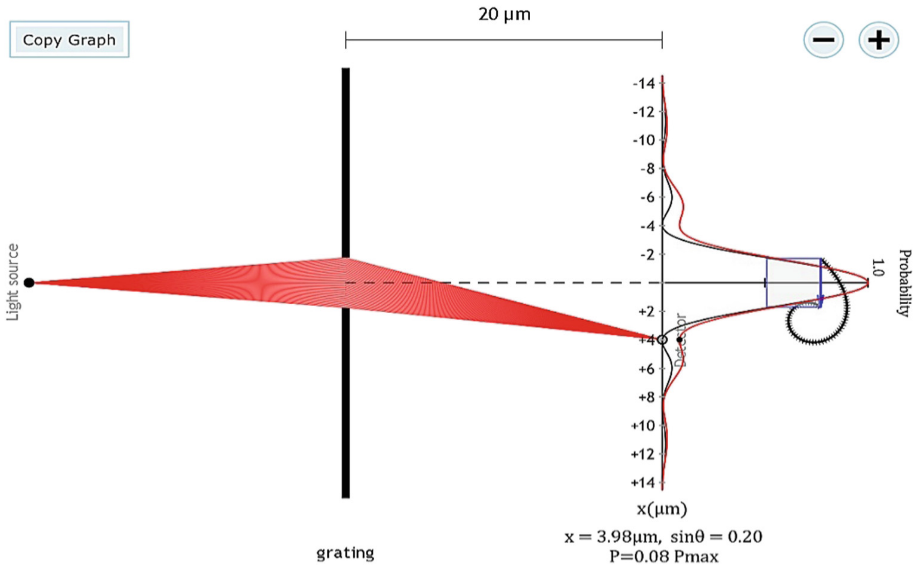

Fig. 8. Fresnel diffraction from a thin slit.

Now the build-in functionality to choose the number of slits will be presented. We will start from the famous two slit Young experiment. To facilitate the presentation, we choose a slit width of a = 0.1 μm, distance of the slits to be b = 4 μm, the distance of the grid to the detector equal to 5 m and the wavelength λ = 700 nm. A depiction of the geometry and the resulted intensity pattern on the screen are shown in Fig. 9.

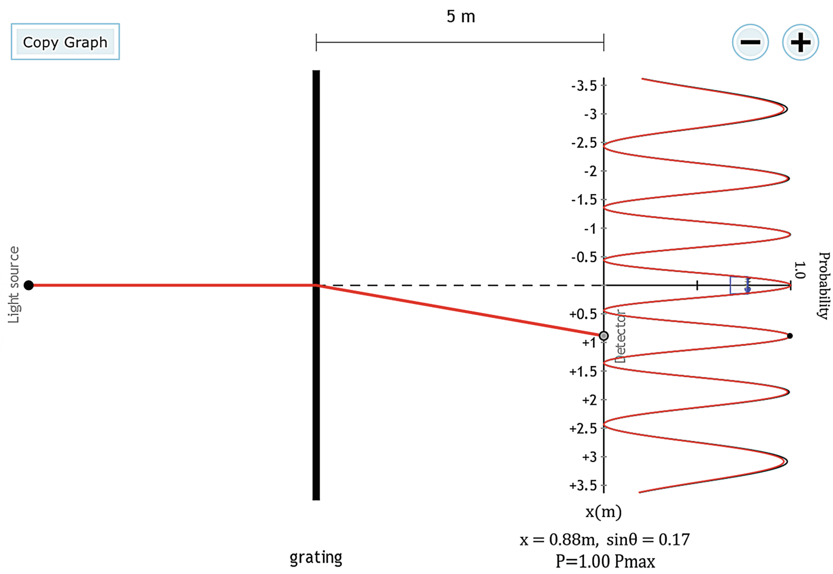

Fig. 9. The two slit Young experiment.

One can ascertain that the resulting pattern confirms the expected positions of the fridges by using the formula derived from the far field approximation. As an example, the first maximum is 0.88 m from the central fridge or $\sin\theta = 0.17$. This measurement agrees with the analytic formula which show that $\sin\theta = \lambda/\alpha$ or $\sin\theta = 0.175$.

The comparison between the analytic result for the specific Fraunhofer approximation of the intensity of the interference pattern and the resulting pattern from the QED simulation can be activated by checking the «Fraunhofer Graph». Since the simulation is done in the regime where the Fraunhofer approximation is valid, we can hardly notice any difference when we superimpose the two cases. Some minor differences start to become apparent for fridges as far as 3 m from the central fridge, and that concerns only the height of the peaks, not their shape or position.

A more realistic picture of the interference pattern can be presented in the «shadow» box, as can be seen in Fig. 10.

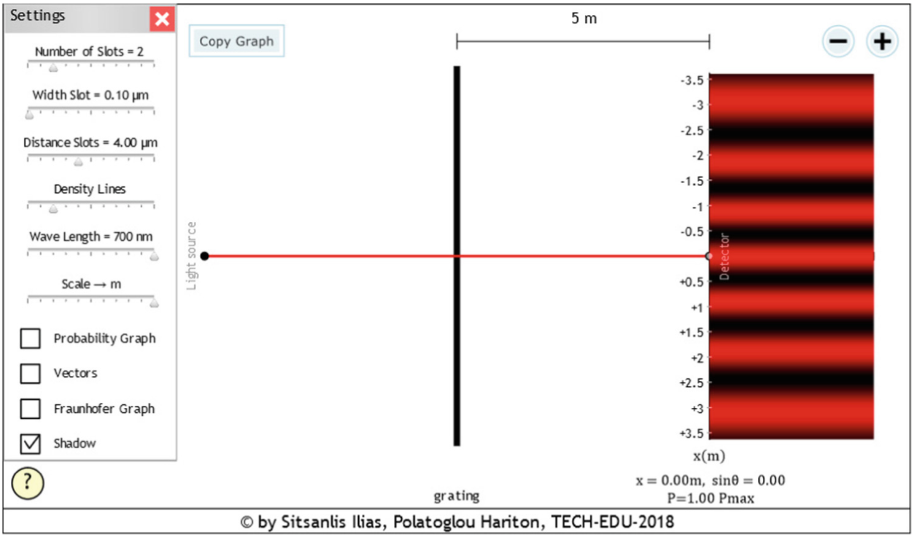

Fig. 10. Realistic interference pattern from the two slit Young experiment. The color is red as it corresponds to the 700 nm of the light used. (Color figure online)

The number of slits and their geometric characteristics can be changed to study other important manifestations of optical phenomena. As a case study, we set the number of slits $N = 5$, $\alpha = 0.1$ μm, $d = 2.5$ μm and $\lambda = 400$ nm. We know that the far field approximation shows that the maxima occur when $\sin\theta = m \cdot \lambda/d$, and for the third maxima when $\sin\theta = 0.48$. This can be easily verified from Fig. 11.

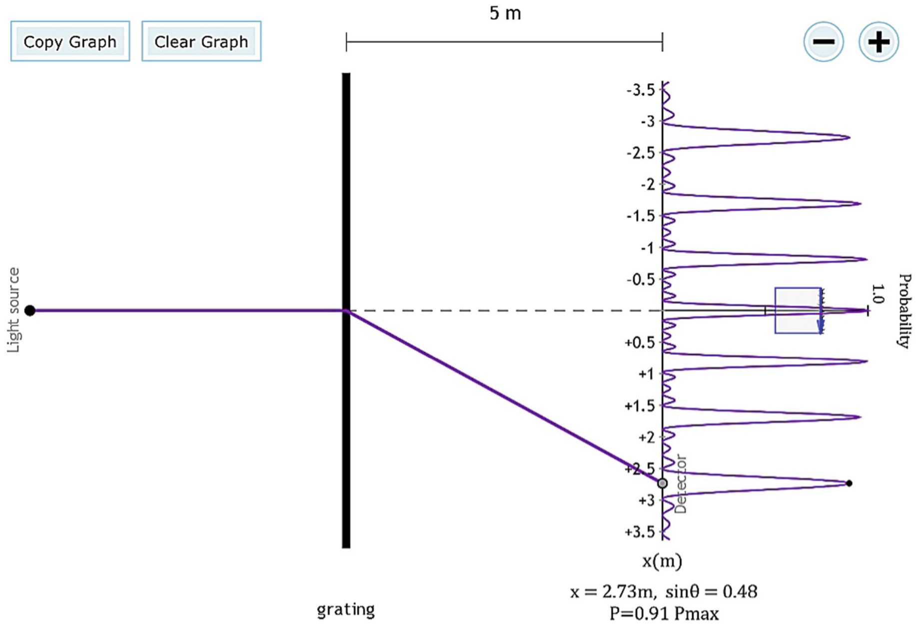

Fig. 11. Diffraction pattern from a grid with $N = 5$, slit width = 0.1 μm, slit distance = 2.50 μm, and $\lambda = 400$ nm.

In all the above cases, for each parameter set one can observe the result of a single simulation. Some interesting cases can be studied if one can compare results from different simulations where one parameter is changed. We will consider as an example the effect of different λ. The first step is to perform a simulation with, let us say, λ_1 and then press the button "Copy graph". That creates a copy of the intensity graph, which can be used as an overlay in another simulation to facilitate the comparison. Figure 12 presents an example, where λ_1 = 400 nm and λ_2 = 600 nm. For that case, we can notice that there is a shift of the peaks for λ_1 = 400 nm to higher distances from the central peak compared to λ_2 = 600 nm, the central peak is on the same position in both cases, and the second peak for λ_1 = 400 nm coincides with the third peak for λ_2 = 600 nm. This type of functionality can help to invoke the scientific method of study by changing one parameter and observe the result. It can be verified, since the maxima occur when $\sin\theta = m \cdot \lambda/d$ and therefore it is possible for peaks to coincide if the equation $m\lambda_1 = k\lambda_2$ has integer solutions. For the presented case one solution corresponds to $m = 3$ και $k = 2$, as the comparison shows (Fig. 12).

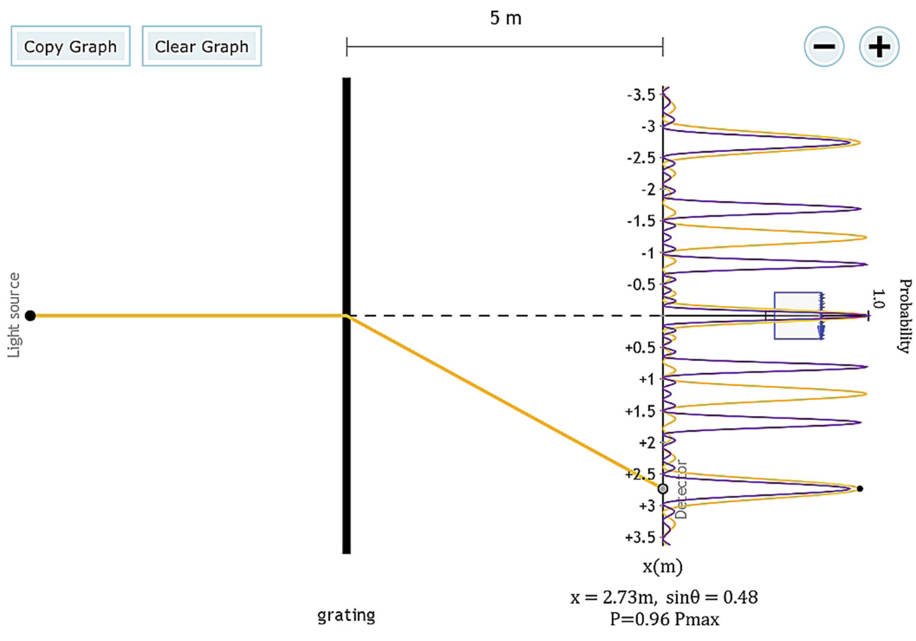

Fig. 12. Diffraction grating with $N = 5$, slit width = 0.1 µm, distance between slits 2.50 µm, λ_1 = 400 nm λ_2 = 600 nm. Notice that the second maxima for the violet coincides with the third for the orange, since $\lambda_1/\lambda_2 = 3/2$. (Color figure online)

The work of Jozef Hancal και Slavomir Tuleja [14] is similarly based on the Feynman rules but it is not as complete and functional as the present realization. In addition, it uses Modellus and Java which are not functional in present day platforms.

3 Simulations

The present simulations are written in HTML5 to operate on every current smartphone, smart TV, tablet, and desktop computer. Only a browser is required. Previous works on the subject [15] were based on executable files which apart for security reasons are not compatible with present day platforms.

For the core of the simulations we use the free software createjs and easeljs of cAs [16] and for the interface Adobe's Animate CC.

One of the basic operations is the production and control of a curve that connects the source (A) and the detector (B). Both the position of the detector and the source can be set interactively by the user. To avoid any complicated schemas, we have decided to include only two points, presented as small empty circles. Those points can be interactively positioned by the user and together with points A and B define a quadratic Bezier curve [17]. Different Bezier curves can be obtained by changing one parameter, i.e. u. A problem which arises is that the length of the curve from A and B does not depend linearly on the parameter u. This is necessary to plot the trajectory of a photon on the curve with constant c. We have calculated for each u the length of the path creating a function s = s(u). Utilizing s(u) we could calculate the photon time of flight and the angle of rotation of the related vector.

The estimation of the resulted intensity could be easily and efficiently obtained for a general path if around the path we can create neighboring paths. This is done with button (+). By pressing it 30 neighboring paths are produced and used to estimate the intensity. For educational reasons the user can put the created arrows in succession to produce the result. The result is also produced automatically to shorten the time needed to study a case.

By pressing the ↑↓ keys a smooth motion is produced and it makes apparent the transition from almost zero intensity for paths away from the straight line of propagation to the maximum intensity for the straight-line propagation.

The introduction of an opaque surface between the source and the detector with controlled openings allows studying diffraction from one slit, two slits and grating using Feynman's rules. The user can choose the number of slits, their distance and width and the radiation wavelength. Changing the number of paths to be considered in each study, one can estimate the intensity better, but such cases are computationally intensive.

It is obvious till now that through the proposed simulations one can study a plethora of phenomena and more importantly all these are manifestations of the fundamental way photons propagate and get detected. Without any intervention to the rules we can reproduce attributes like particle or wave thus underlining the unity of nature. We have seen that the same rules reproduce the straight-line propagation of light in free space or if it passes through a wide slit, usually attributed to the particle nature of light and the diffraction from a relative small slit width, which usually attributed to the wave nature of light.

The same holds for the two-slit interference, where we can seamlessly study the effect of interference due to the two slits and diffraction due to the width of each slit. More specifically, one can notice that the diffraction effect is small when each slit has a small width and strong otherwise. Increasing the number of slits a diffraction grating is manifested and the investigation of the secondary maxima is feasible. By overlapping diffraction patterns from different wavelengths one can access the resolving power of a grating and appreciate its use as spectrum analyzer.

An additional feature which we have introduced is the possibility to change the distance between the detector and the grating, thus allowing the transition from the far field condition to the near field [13] and observe real interesting phenomena, which otherwise require difficult analytical tools.

4 Conclusions

The teaching of quantum physics encompasses many difficulties as many pertinent notions are strange compared to the everyday experiences. This mysterious branch of physics fascinates students and induces curiosity. Otherwise, for a, thorough study there is a need to resort to difficult mathematics.

The ICT technologies provide the tools so that important physics topics could be presented in an intuitive way and in an environment where students are very familiar with.

We have designed and developed a set of simulations for the study of the application of QED to optical phenomena. These simulations are not based on the calculation through some known formula but rather incorporate the physics of the way photons propagate and are detected. With the above simulations, students can access a topic in modern physics, apply the scientific method and study the phenomena of diffraction and interference. The last case occurs when there are more than one slits.

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Interactive Video for Learning: A Review of Interaction Types, Commercial Platforms, and Design Guidelines

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Abstract. In recent years, there has been a sharp increase of research in employing interactive video for learning. More researchers study both the functional and cognitive interactivity affordances of educational interactive video and try to identify the learning effectiveness of the various supported interactions. In this study, we aim at providing a review of the interactivity types and their educational value based on the analysis of 18 studies and 13 commercial interactive video environments. We also analyze whether the commercial environments keep up with the research trends. Finally, we provide specific design guidelines for developing effective educational interactive videos. Such holistic review approaches help to promote the research field in everyday educational environments but also reveal its promises and gaps. The educational interactive video seems to be a fast-changing field which needs further inquiry, while the available commercial platforms have just started to incorporate functionality proposed in the literature.

Keywords: Interactive video · Hypervideo · Video-based learning

1 Introduction

1.1 A Subsection Sample

Video has been identified as one of the most differentiated and effective virtual learning mediums and video-based learning techniques have been used in various settings such as the "flipped" classrooms, or MOOCs. Video offers a sensory learning environment with a touch of face-to-face human texture that supports learners to understand more and recall information better [1, 2]. However, learning with video is not straightforward, and, for example, it is well-known that linear video may become a passive experience and may lead to superficial learning and insufficient viability of the learning effect, what is called the "couch-potato-attitude" [3].

Interactive video - also called "hypervideo" - has been developed for addressing exactly these issues. Interactive video offers several interactivity options over or next to the video with the aim of providing a more engaging and active watching experience.

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Users can answer questions, click on interactive regions over the video, select how the video story will develop, click on external links, access additional information, etc. [4]. New interactive video authoring tools are easy to use and the interactivity features can be built even on top of common video services such as Vimeo or YouTube (e.g., hapyak.com, raptmedia.com, edpuzzle.com, koantic.com, learnworlds.com/). With a few clicks, a video can become interactive without the need of the typical time-consuming video editing process.

In this study, we propose a new categorization scheme for video interactions and we describe their educational value. Based on this categorization scheme, we present the interactivity features of 11 commercial interactive video platforms and comment on whether they keep up with the research trends. Our study concludes with a compilation of design guidelines for offering effective educational interactive video. Such holistic reviews help to promote the research field in everyday educational environments but also to reveal its progress and gaps.

2 Educational Interactive Video

Most studies adopt a standard definition about the interactive video: "A non-linear, digital video technology that allows students to have their full attention to educational materials and to review each section of video as many times as they wish" [5, 6]. Meixner [7] defines interactive video as video-based hypermedia that combines non-linear video structuring and dynamic information presentation over and next to the video.

Interactive videos have many educational benefits. Several studies have demonstrated that interactive videos can increase students' motivation [8], satisfaction [5, 9] and also performance in learning [4, 8]. Video interactivity is considered as flexible, motivating [6] and entertaining [7]. Interactive videos facilitate differentiated and personalized learning since they allow learners to act independently, follow their path and maintain their pace [10, 11]. They increase learners' satisfaction over the educational process and transform passive watchers into active learners.

Wouters et al. [12] support that there are two layers of learning interactivity, the first layer is the functional interactivity on students' actions and the second layer concerns cognitive interactivity which refers to calls for action that trigger cognitive and meta cognitive processes. For example, a challenge to predict what will happen next in the video could cause students to experience an expectation failure [13] and thus, come into conflict with their previous knowledge. Both interactivity layers seem to have significant learning results [14]. Similarly, other studies have shown that as students navigate freely in interactive videos with the help of indexes, pointers, and external links, they organize better information, find deeper meanings and link them to previous knowledge, experience and mental structures [14, 15]. Cairncross and Mannion [16] also underlined that the interactive video increases students' ability to transfer knowledge from the short-term to the long-term memory. All of the above contribute to an enjoying educational experience with enhanced learning outcomes and better knowledge retention [14].

3 Interaction Types

In a recent review, Schoeffmann et al. [10] classify video interaction methods in the following categories: Video Annotation, Video Browsing, Video Navigation, Video Editing, Video Recommendation, Video Retrieval and Video Summarization. Another classification of interactive elements can be found in Seidel's research about interaction design patterns on video [17] while Papadopoulou and Palaigeorgiou [4] proposed interactivity categories based on their pedagogical purposes, i.e., rhetoric questions or inductive questions.

We analyzed eighteen studies concerning interactive video, as well as eleven commercial interactive video platforms and created a new classification scheme including five main interaction categories describing the educational opportunities of interactive video: Authors' annotations, Users' Annotations, Between Users Interaction, Video Navigation, and Summarization. Interaction types found in each study or platform are shown in Table 1. Many categories include more detailed interaction types.

3.1 Author's Annotations

Annotations are media (images, text, etc.) that appear inside or next to the video with the aim of facilitating understanding. Their display is synchronized with specific video frames. New interactive video platforms enable the author to add such elements in a matter of seconds. Annotations can be static, without any interactivity for the learners, or dynamic, but both aim at promoting learners' engagement with the presented learning content [20]. Most common author's annotations are:

Overlay Elements. Overlay elements include all types of elements that can be added over the video such as textual representations (i.e., titles that describe objects), images, hyperlinks (to websites, PDF documents, social media services or other videos), maps and audio-files. These elements are positioned usually in relation to the visual structure of the presented video frames and are synchronized for specific duration. They are easy to add and may serve different learning objectives.

Side Media. Side media refer also to elements that are synchronized with segments of the video but which are presented side-by-side (i.e., slides, narration text, etc.). Side media usually create a peripheral supportive learning area next to the video. Usually they are more expressiveness with fewer appearance restrictions since they do not alter the video layout regardless of their size or type.

Highlighting. Highlighting refers to the various kinds of pointers or objects that are added over the video frames with the main goal of drawing learners' attention to specific frame areas. Highlighting elements guide learners' attention and provoke them to focus, think or discuss with their partners the most significant issues presented.

Captions. Since videos are often dedicated to a diverse audience with different language competencies and abilities, most platforms offer the possibility to provide captions [17]. Interestingly, the captions mechanism can also be used as a method for providing different levels of textual descriptions which the learners can select based on their understanding or learning needs.

Embedded Questions. Embedded questions are probably the most often used feature of educational interactive videos. Questions foster a more profound engagement of viewers and also serve as assessment tools. Embedded questions increase the interaction of the students with the learning materials [15]. Their display may stop the video to wait for learner's answer. However, there are also cases where the questions are optional and appear together with a timer that shows for how much time the questions will be displayed on the video.

Hotspots. Hotspots are clickable areas in a video (e.g., buttons, regions) which may present further information, navigate learners to external links or different positions inside the video or function as answers to embedded questions. Hotspots make possible interactivity which is directly connected with the contents of the video.

3.2 Users' Annotations

Users' annotations concern personalized learning actions such as keeping personal notes, adding annotations or bookmarks, creating spotlights and marks on the video [18]. The annotations are automatically synchronized with the time they were created and work both as reflection triggers and as a navigational means. Annotating the video promotes a feeling of video ownership to the viewer and usually results in more active engagement.

3.3 Between Users' Interaction

The introduction of synchronous and asynchronous interactions among video viewers is a promising approach to increase constructive user engagement with the video content. Such interactions try to strengthen the community awareness and to take advantage of the collective intelligence of watching a video for learning purposes. For example, the visualization of other learners' traces on the video progress bar enable users to identify which segments of the video are more viewed and probably are considered as more important. Other examples of between users' interaction are commenting, peer annotations and peer assessment [17].

3.4 Video Summarization

Summarization is a method that enhances learners' engagement with video content since it concerns the creation of a short clip or a textual outline of the entire video. This summary of the video aims at helping learners organize better the information presented and reduce the time spent on revisiting the contents. Summarization techniques can be (a) automatic, meaning that videos can be summarized based on image processing, text or keyword extraction techniques, [19] or (b) non-automatic, meaning that viewers can create summaries by selecting specific parts of the original video manually. The latter can be considered as a constructive and knowledge-building experience since students have to think and link several video segments in a meaningful way for them [20].

3.5 Navigation

According to Meixner and Gold [21], video navigation can be discerned in two categories: navigation options appearing at the end of the video and global navigation. When a video reaches its end, usually plenty of options appear promoting different navigation actions, i.e., see a related video, replay the video, etc. Global navigation concerns the affordances that allow users to access fast and with accuracy, exact points in the video that present content of special interest to them, e.g., a table of contents or a search function. Frequently interactive video navigational options are:

Table of Contents. Navigating randomly on a timeline or a video progress bar is a time-consuming task. A table of contents provides quick access to different content segments inside a video. Each section comprises a meaningful unit that is summarized in the section heading inside a table of contents or the progress bar. Therefore, table of contents also help users to get an overview of the whole video contents.

Content Visualization for Video Browsing. Content visualizations are similar to content tables since they provide a clickable overview of the video contents [21]. However, they are created automatically by capturing still frames of the video in several ways. Content visualizations are a more vivid way of disclosing the contents of a video and help the learners select visually their next steps.

History Browser. History browsers are created based on user's navigation history inside the video. First users' navigational actions are recorded, and then simple mechanisms are offered to quickly find and watch previously viewed intervals. For example, segments of the video that the user found interesting maybe highlighted [22]. Interestingly, history browsers add value to users' prior navigation actions.

Search Function. A search function offers users the chance to be transferred to specific video segments according to their text or visual input. Searching the video usually requires pre-processing its contents with image, audio, and video analysis methods and extracting meta-data that index important information for later search and retrieval purposes. These metadata may also be added/updated manually by the video author.

360-degree Video and Multicamera. Many new interactive video platforms provide the viewer with 360° video experience usually enriched with additional interactions (e.g., Page-flow, Wirewax). Similarly, multi-camera (or multi-view) video also offers viewers the opportunity to navigate between different angles of the same scene. In both cases, the user decides what to see from a predetermined set of options. These options provide a more personalized experience of watching the video.

Playback Speed. Users in most current video platforms can configure the video speed as well as the direction of the playback. The various speeds allow the learners to set a learning pace that is adequate for the different segments of the video and their prior understanding. This possibility is also useful if the user wants to take notes or add annotations [17].

Branching. Some interactive video platforms provide the opportunity to link separate videos in a tree-like structure and let users decide which route to follow by clicking on interactive elements over the video (ex. SIVA Producer [12]). Quite often the users cannot identify when each separate video starts or stops and they feel like watching a single video. Branching enables users to drive their experience, skip content, and study information at a self-determined pace. In that case, each user watches a different version of the video. Branched videos help learners stay focused in the content and be more engaged.

Table 1. Video interaction types.

Interaction types	Studies and tools	Interaction types	Studies and tools
Creator's annotations		*Video navigation*	
Overlay elements	[31, 32]	Table of contents	[42]
Side media	[33]	Contents visualization	[43, 44]
Highlights	[33]	History browser	[32]
Hotspots	e.g., Wirewaz, Vidzor	Search function	[45]
Captions	[31]	Multicamera – 360° video	[46]
Embedded questions	[15, 34]	Playback speed	[47]
User's annotations		Branching	e.g., Wirewax, HapYak
Overlay elements	[35]	*Between users' interactions*	
Highlights	[34]	Discussions around content	[37]
Linked comments	[36]	Pop-ups	[38]
Video summarisation		Comment ratings	[39]
Automatic summarization	[40]	User traces	[24]
Non automatic summarization	[41]		

4 Educational Perspectives

An interesting question is what kind of cognitive and meta cognitive processes may be triggered by each interaction type, as this would help us better understand interactive video's educational potential. In Table 2, we offer a proposal of all learning objectives that may be addressed from each interaction type. Instructors exploit interactive video mainly to address the following learning goals:

Active Studying of the Video Content. Note taking, highlighting or creating personal summarized video improves focus and active learning since students have to listen/watch carefully and decide what to include to their notes, they have to emphasize and organize information better. The related actions produce a condensed record for later study and review.

Draw Attention to Critical Information. Information processing can be facilitated through signaling. Mautone and Mayer [31] argued that signaling can help to emphasize particular aspects of content (and therefore reduce split-attention effect) but also to underline the correlations between concepts, which is often difficult for the students. Highlighting and hotspots draw the attention to specific visual aspects of the video. Thus they support mental selection and organization during observation.

Information Recall. Information recall is mainly achieved through embedded questions and the various means of replaying the video, from the table of contents to looping (replaying the video). For example, pre-adjunct questions help in attention stimulation, while post-adjunct questions promote information recall.

Reflection. Reflection is one of the critical stages of learning [23]. Through reflection prompts within a video (e.g., the video pauses in the context of a problematic situation and urges the students to reflect about strategies they have used in the past) students inspect the video contents critically. Shared users' annotations and traces also trigger students to discuss, reflect and draw conclusions about their strategies.

Knowledge Construction. Interactive video may include hyperlinks and choices that function as knowledge construction tools and help learners own the learning process and think more productively. Hyperlinks and branching allow a specific topic to be explored in multiple ways using different concepts or themes while facilitating cognitive flexibility on knowledge construction [24]. Non-automatic summarization also may offer a constructive learning experience.

Cognitive Conflict. Cognitive conflict occurs when a student's mental balance is disturbed by experiences that do not match with their current understanding [25]. This conflict can lead to conceptual change over topics students have misunderstandings. Cognitive conflict can be applied through embedded questions into the video that will help students expose their misconceptions, realize their inaccuracy and their inability to predict what will happen next. Video has the advantage of improving the plausibility of the presented proofs.

Collaborative Learning. Although collaborative learning is the less recognizable feature of an interactive video, it is one of the most powerful. Shared annotations or notes, commenting connected with specific time frames, summative user traces and ratings can all activate the collective intelligence of the viewers of the same video. Users' actions and comments are situation-driven and their exchange can support learners' understanding and critical thinking.

In the following table, the video interaction types are related with the different learning objectives considered.

Table 2. Interaction types and learning objectives

Interaction types	Active studying	Attention	Information recall	Reflection	Knowledge construction	Cognitive conflict	Collaboration
Creator's annotations							
Overlay elements		X			X		
Highlights		X			X		
Hotspots	X	X					
Clickable elements		X			X		
Side media					X	X	
Embedded questions			X	X	X	X	
User's annotations							
Overlay elements	X		X	X			X
Highlights	X		X	X			X
Linked comments	X		X	X			X
Between users' interactions							
Discussions around content	X		X	X		X	X
Pop-ups	X						X
Comment ratings	X						X
User traces	X			X			X
Video summarisation							
Automatic summarization			X				
Non automatic summarization	X			X			
Video navigation							
Table of contents	X				X		
Contents visualization	X				X		
Search function	X				X		
History browser	X		X				
Multicamera – 360° video	X				X		
Playback speed	X				X		
Branching	X				X		

5 Commercial Interactive Video Platforms

Although many studies concern interactive video platforms, most of them are created as research products and are not available to the public and, therefore, have limited practical value. However, there are several commercial interactive video platforms which provide a variety of tools and features. This section presents the most well-known commercial platforms along with their main characteristics. Platforms included in our study can be exploited for educational use, while the platforms excluded are pursuing interactivity for marketing purposes. As seen in Table 3, most platforms already support several types of interactivity.

PlayPosit (https://www.playposit.com/) is a free online learning environment to create and share interactive video lessons with groups of students. PlayPosit is designed to be used in flipped, and blended environments.

Adways (http://www.adways.com/) interactive video technology provides users with a significant number of possibilities for interactive video design. The instructor can show additional information inside or outside the video and give the ability to students to alter the storytelling of a video depending on their choices and actions.

EdPuzzle (https://edpuzzle.com/) provides a simple video editing toolset that may transform a video into an interactive lesson that is personal, engaging and effective. ED puzzle provides three main interactive elements: a crop tool, addition of voiceover/audio notes and embedded questions with feedback.

Adventr (http://www.adventr.tv/) helps users design interactive videos and also provides actionable analytics. Adventr is a simple platform where content makers drag and drop their clips into templates. The platform enables designers to create specific paths of videos based on users' responses.

Wirewax (https://www.wirewax.com/) is widely used in education, in marketing, and in entertainment. The platform provides a variety of interactive elements such as automated hotspots (e.g., automatically detects people, objects, and products). Hotspots also can follow the motion of the object tracked as it moves in the scene. Wirewax supports branching, chaptering, 360° Interactive video and slider/multi-video playback.

Vidzor (http://vidzor.com/) is an interactive video platform that enables users to create an engaging video with HTML5 technology. Designers can upload their files and add certain interactive elements: Skipping, looping, video linking (which connects two videos), clickable hotspots, closed or open questions, votes, donations, a form builder for getting textual input and clickable maps. The platform also provides teachers with analytics of users' views.

RaptMedia (http://www.raptmedia.com/) is an interactive video application that combines a path-editor and an interactive video composer. Creators can build personalized view paths and also add clickable hotspots on each separate video.

H5P (https://h5p.org/) is an HTML5-based open source interactive video platform that allows users to create video experiences with multiple response questions, fill in the blank questions, interactive summaries, single choice question sets, simple overlays with text and images, tables, labels, and links.

Comment Bubble (https://commentbubble.com/) combines a student-response component and an analytics tool for reviewing users' responses. Creators can add

Table 3. Platforms and supported interactions

Interaction types	PlayPosit	Adways	EdPuzzle	Adventr	Wiremax	Vidzor	RaptMedia	H5P	Comment bubble	HapYak	Learnwords
Creator's annotations											
Overlay elements			X		X	X	X	X		X	X
Highlights	X	X	X	X	X	X	X	X	X	X	X
Hotspots		X			X	X	X			X	X
Side media											
Embedded questions	X	X	X	X	X	X	X	X	X	X	X
User's annotations											
Overlay elements											
Highlights											
Linked comments									X		
Between users' interactions											
Discussions around content									X		X
Pop-ups		X									
Comment ratings									X		
User traces											
Video summarization											
Automatic summarization					X						
Non-automatic summarization											
Video navigation											
Table of contents		X		X						X	
Contents visualization											
Search function											
History brower											
Multicamera – 360° video					X						
Playback speed											X
Branching				X	X					X	

videos from Vimeo or Youtube and ask for feedback from their viewers as they watch the video. That way, creators can assess learners' understanding or opinions upon certain moments. Quick comment categories allow creators to specify the type of feedback they would like to get.

HapYaks (https://corp.hapyak.com) works with any digital video and offers a template library that lets instructors to instantly add or modify overlays, chapters, links, branching, embedded questions and a lot more.

LearnWorlds (https://www.learnworlds.com/) is an online course platform that allows instructors to design courses that may include questionnaires, tests, e-books, and interactive videos. LearnWorlds interactive videos enable creators to add several types of annotations (hotspots, augmented elements, text phrases, titles, etc.) clickable or not, add overlays as reflection activities or add questions with feedback. LearnWorlds offers a rich library of pre-designed interaction templates.

As seen from the table above, most commercial tools are focused on facilitating their customers' needs and, hence, they are mainly offering a rich variety of annotations for the instructors. There is a limited focus on personalized tools for the video viewers and even less interest for taking advantage of the collaborative potential of interactive video. Summarization and advanced navigation facilities have also not been exploited extensively. The commercial interactive platforms do have a lot of educational potential to unlock.

6 Designing Educational Interactive Videos

Until this point, we have presented different interactivity types, their pedagogical value and various commercial interactive video platforms. The last link of this value chain is guiding the development of effective educational interactive video. As previously stated, when designing interactive educational videos, instructors should not be concentrated only on the functional interactivity, but more importantly, they should emphasize on the underlying cognitive interactivity [26] (e.g., feedback after the student's answer). Although there are plenty of guidelines for developing educational video [27], here, we try to compile a set of guidelines concerning instructors' annotations in interactive videos:

Avoid Heavily Annotated Video. Designers should avoid adding extraneous information in their video, which may be interesting but doesn't contribute to the learning goal (a process known as weeding). However, information that may be extraneous for a novice learner may be helpful for a more expert-like learner [25]. In interactive video, there is always the possibility to address different audiences through non-mandatory annotations.

Set Fixed Positions for the Annotations. Video designers should determine fixed locations for annotations at the margins of the video frame or even outside the video [17]. This way, viewers can hide them individually or all together when they want to focus on the video itself or return to the annotations later.

Let Users Decide if They Want Side Content. In the same spirit with the previous guideline, viewers tend to split their attention between the video and the synchronized side contents, and, hence, cognitive overload may be provoked. It is crucial to provide users with the possibility to decide whether side content should be displayed smaller, larger, or not at all.

Use Pre-adjunct Questions. Pre-adjunct questions serve as a method or tool for stimulating the learner's attention and motivate them to focus more on specific aspects of the learning material. Such questions help students to form a focused perspective for watching the video and help them to select and organize the presented information.

Create Reflective Pauses. Reflection prompts are a vital component of successful learning. When video pauses and urges students to think about their choices, they reflect on how they performed a task and deepen their understanding. Students expect that their thoughts will have some relation with what will follow in the video.

Induce Information Recall. Post-adjunct questions (at the end of a video or a video segment) reinforce the presented knowledge and encourage learners to build explanations and expectations that go beyond the learning material [28]. Use either memorization (recognition or recall) questions or application questions. A non-automatic video summarization activity may also be considered as a post-adjunct reflection action.

Provoke Predictions. Use questions while a video is playing and give learners the opportunity to predict what is going to happen next. A challenge to predict the next event or effect, guide viewers to expose their misconceptions and evaluate their understanding. Video, as mentioned earlier, has the advantage that it is perceived as a trustworthy source of information by students.

Provide Formative as well as Summative Assessment. Informal quizzes and questionnaires can be included in specific points of the video and may provide meaningful feedback that guides students focus and next navigational choices [29].

Give Feedback to Students' Answers. Feedback is essential for providing the necessary scaffolding to learners and close the gap between current and desired performance [30].

Allow Your Learners Define the Development of the Video Story. When designing a video, it is essential to allow a second-layer navigation, especially when the video is too long. With second-layer navigation [21], viewers can jump to specific scenes in the table of contents or the graph structure. With branching, instructors can offer multipath videos for their students. Second-layer navigation demands an excellent design, production, and structuring of the video content in order to be feasible to offer a unified learning experience.

Encourage Replays. Designers should include enough triggers to make learners want to watch the video again. Repeating an interactive video helps reinforcing its contents.

Track Interactions. Students' video behavior should be tracked and reported back so that an instructor can identify learners who are struggling with specific interactions

[31]. Recording and understanding interactive video analytics is a decisive part of designing successful interactions. Metrics will help interactive video developers to understand their learning audience and optimize the interactivity options.

7 Discussion and Conclusion

In this study, we explored all aspect of interactive video's educational value: we presented a categorization of interactivity types, we discussed their educational value, we presented commercial interactive video platforms while we also offered a set of guidelines on how to develop interactive videos.

There are three conclusions from our review:

- As seen in Table 1, the studies concerning the educational value of different interaction types are a few and a lot more research should be done to reveal the multi-perspective educational opportunities of interactive video.
- As seen in Table 3, most commercial tools are focused only on facilitating instructors in designing annotations and are less interested on empowering learners to constructively watch videos. Table 2 reveals that all video interactivity types can address a variety of learning objectives. Hence, school and university instructors do not have yet in their disposal the full range of educational interactive video affordances.
- Interactive video design is an uncharted design space, and existing guidelines offer an abstract understanding of what an instructor should do. Most propositions derive from cognitive multimedia learning theory while the last few years some studies have started to propose strategies of how to develop embedded questions.

The interactive video seems to be a fast-changing field, and the available commercial platforms have just started to incorporate functionality appearing in research studies. The most important aim of the educational interactive video is to promote active processing through "in context" cognitive interactivity. A considerable number of studies highlight the importance of going beyond interactive video's technical characteristics and emphasize the need to focus on the pedagogical results and the design requirements of video interactivity.

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Enhancing Spatial Ability Through a Virtual Reality Game for Primary School Children: "The Wizard of Upside Down": An Experimental Approach

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Abstract. Spatial perception is a complex cognitive ability, which has been the subject of many studies aiding towards a clarification of its content. The complexity of this skill lies in the many factors that compose it. Some researchers tend to believe that spatial perception is a one-breeder concept, while others talk about two main factors, three or even more. Accordingly, several theories on the evolution of spatial perception have been developed, while the factors referring to the advancement of spatial perception such as gender, age and social factor have been investigated. The present research effort focuses on the development of spatial perception and on the skill of mental rotation through the exploitation of a virtual reality learning game. The design of the virtual environment took place in the context of a Master Program within the Aristotle University of Thessaloniki, while it is planned to carry out research using the "Children's Mental Transformation Task (CMTT)" questionnaire.

Keywords: Spatial ability · Mental rotation · Virtual environment · Educational game

1 Introduction

1.1 Theoretical Framework

Spatial perception is a complex cognitive ability that is linked to success in first-grade pupils' mathematics performance, much more than other factors such as demographic characteristics of participants or language skills [1]. Consequently, spatial perception is a quite intriguing topic among many researchers. The complexity of spatial perception lies both in the number and the naming of the factors that compose it. Although there is no commonly accepted term for spatial perception, according to a recent literature review [2], spatial perception involves everything related to spatial sensing, spatial orientation, creation of mental images, spatial visualization, visual skills, spatial

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reasoning, mental rotations and visual procedures. Nevertheless, to fully clarify the notion of spatial perception, it is necessary to define its structure first.

As stated above, researchers' views on this topic differ. Some researchers [3–5] perceive spatial perception as a one-dimensional structure. In contrast, most researchers claim that spatial perception cannot be consisted of a single factor [6–12]. Disagreements also appear concerning the denomination of the factors as this seems to differ from one researcher to another. Consequently, there is a strong disagreement over the tests used to measure each factor [12, 13].

There have been many researchers conducted by professionals examining the factors that may influence the development of spatial skills. Such surveys seem to have been conducted mainly in the field of psychology and are mostly focusing [14] on (a) age [9, 15–26], (b) gender [10, 27–31] and (c) education/experience in the field [32–36].

Nevertheless, it appears that spatial perception is a cognitive ability that reaches maturity during puberty [24]. Thus, significant results have shown that the best age for the acquisition of spatial skills through teaching is between 11–12 years old [32], while, according to others, the development of spatial perception in children is completed by the age of 9–10 years [37].

1.2 Digital Game Based Learning

Digital game based learning that is activities that utilize computer gaming as a non-trivial part of the learning process [38], have found widespread acceptance in all sectors of human activity. From military training and healthcare [39–41], to education digital gaming is a way to engage the learner and motivate her on pursuing the learning subject on her own, hence increasing learning efficacy (for contemporary reference works on general impact of gaming in education the reader is directed e.g. to [42] and [43]). Summarizing, game based learning's efficacy is drawn from two factors. One is the narrative engagement that stimulates the learners' imagination putting her in realistic or fantasy settings that intrigue and motivate her to solve problems or be exposed to knowledge (cf. [44] and references therein). The other factor is based in the theory of flow [45] and challenge, whereas, when a person is involved in an activity within her limits but near their outer boundaries (challenged but not overwhelmed) then the sense of achievement is a powerful motivating and engaging factor [46].

1.3 Purpose of the Study and Research Question

Although research has been conducted upon the effects of virtual reality games on spatial abilities, fewer studies up to this point used VR or AR to study small-scale aspects of spatial ability [47]. The results of most of these studies are limited to the analysis of gender-based data focusing especially on adult subjects.

The current study is innovative in relation to the advancement of knowledge about the impact of a virtual environment game on the spatial ability of young children and the development of their spatial reasoning through playing. Firstly, by focusing on 2D and 3D representations of mental rotation activities in a 3D virtual environment, and secondly by addressing a research gap about how Greek-speaking children can develop their spatial thinking via a virtual environment which calls them to solve mental rotation exercises inspired by everyday life. The Research question being examined is:

What effect does encouraging the use of a virtual environment game for spatial skills have on children's spatial reasoning ability, and specifically on their mental rotation skill?

2 Methods

The current study serves as a research base, describing an experimental design to examine the causal link between educationally relevant virtual environment game use and student's spatial performance in a sample of first or second grade primary school students. The game "The Wizard of Upside-Down" starts with a scene where the player is informed that the wizard has messed up the village and took our hero's three friends and locked them in a cell in his magic tower. The Wizard of Upside-Down meets Prensky's six basic characteristics of a game [48], as the lead player aims to save his/her friends from the Wizard, who overturned everything in the village and imprisoned his/her friends in the castle (Figs. 1, 2 and 3). At the beginning of the game, the story, instructions and the rules of the game are given. The player is asked to find the village to find the three golden keys to release his/her friends. The three keys are in the post office, the bakery and the grocery store where the wizard has mixed things up in the shops and the player has to help and pick things up and in return he/she gets the keys.

The activities are placed in the game based on their level of difficulty. There are 7 activities in total, 2 in each shop (post office, bakery and grocery store) and 1 final activity. In the activities 1, 3, 5 (Appendix, Figs. 1, 3 and 5) the user has to select the 2d object that matches the shade displayed. The activities 2, 4, 6 (Appendix, Figs. 2, 4 and 6) involve 2d puzzle assembly in which the user has to choose the pieces of the puzzle and place them in the correct position to complete the puzzle image. The last activity (Appendix, Fig. 7) regards the assembly of 3d cubes, so as to form the invisible magical door of the tower in which the friends are imprisoned. With the successful assembling of the cubes, the friends are released and the game ends. The image choices in the activities have been reflected and undergone some sort of rotation (Act. 1, 3 and 5) or just have been rotated (Act. 2, 4 and 6). All activities mentioned so far aim to practice mental rotation, since the user has to mentally move and bend all the 2d objects in space to find the right answer.

The game belongs to the adventure games based on Prensky's taxonomy [48], where the player tries to find his way into an unknown world, find hidden objects and solve puzzles.

3 Experimental Design

The activities mentioned above are designed according to the theoretical framework in relation to how mental rotation has been described, that is "the mental cognitive process of moving and bending an object in space" [9] and are based mostly on improving mental rotation and spatial orientation skills in students who are at the beginning of the most influential ages to develop spatial skills.

"The Wizard of Upside-Down" was developed as a non-immersive educational virtual environment as Mikropoulos and Natsis have defined [49] exploiting free navigation and first person experience, while it can be reconstructed in multiple versions. The game's virtual environment and activities were created with Unity [50], since Unity is an ubiquitous platform which gives the option of multiple builds such as Virtual Reality (VR), Augmented Reality (AR) and Mixed Reality (MR) applications. For the assessment of research outputs students will be given the "Children's Mental Transformation Task (CMTT)" and the research will be carried out in accordance with the protocol used in previous researches [51]. Researchers used two-dimensional stimuli that were divided in half by the vertical line of symmetry. The two halves were shown to children either rotated or translated apart. Participants were shown the divided shape and asked which of four whole shapes the two pieces would make if put together. Participants will be given 16 pretest items and 16 posttest items (all items will differ from one another) while in the meantime will be implemented the planned virtual educational game. Before the test is applied to the subjects of the survey, details will be given on the procedure as well as an example of the test images. The time distance between pretest and posttest will be 2 weeks while they will play the game two times.

4 Discussion

Our research is estimated to last two months. In these two months, the development of "The Wizard of Upside-Down" will be completed and interventions will be carried out on a sample of students aged 6–7 years at a local school in Thessaloniki. Then, the collected data will be analyzed and the final conclusions will be drawn on the effect of a virtual educational game on students' spatial skills.

Regarding the improvement of this study, we consider it necessary to carry out further research on a larger sample. Furthermore, research could focus on different versions of the game using real 2-D environments, non-immersive VR (Computer screen) and immersive VR (HMD). In addition, the game can be enriched with more 3d or 2d activities, to further improve the spatial skills of the students beyond the aspect of mental rotation. Finally, we propose the construction of a teaching plan that includes the educational game "The Wizard of Upside-Down".

Appendix

(See Figs. 8, 9 and 10).

Fig. 1. Activity 1.

Fig. 2. Activity 2.

Fig. 3. Activity 3.

Fig. 4. Activity 4.

Fig. 5. Activity 5.

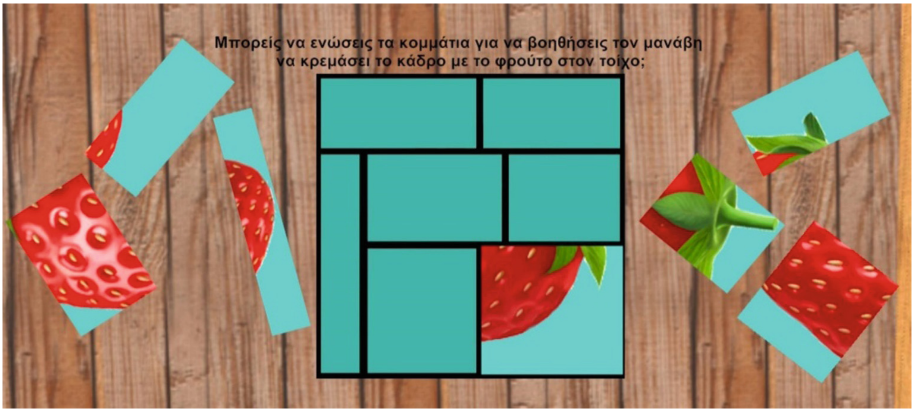

Fig. 6. Activity 6.

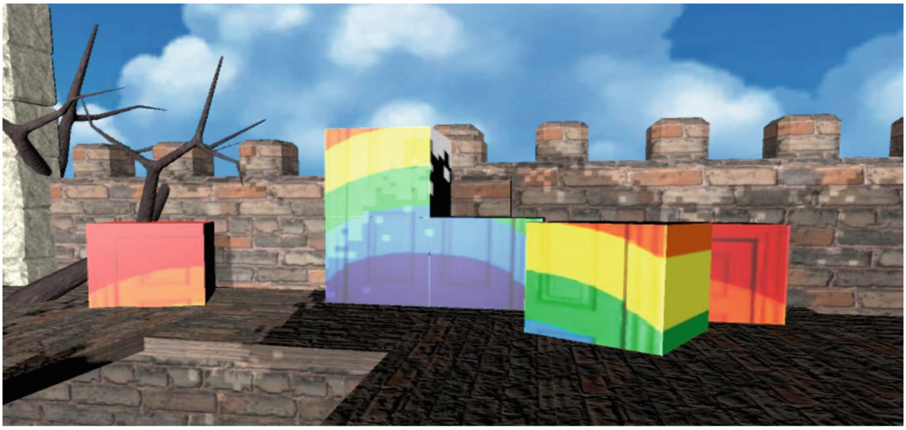

Fig. 7. Activity 7.

Fig. 8. Panoramic view of the village.

Fig. 9. Houses into the village.

Fig. 10. The entrance of the castle that leads to the final activity.

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Student Concentration Evaluation Index in an E-learning Context Using Facial Emotion Analysis

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Abstract. Analysis of student concentration can help to enhance the learning process. Emotions are directly related and directly reflect students' concentration. This task is particularly difficult to implement in an e-learning environment, where the student stands alone in front of a computer. In this paper, a prototype system is proposed to figure out the concentration level in real-time from the expressed facial emotions during a lesson. An experiment was performed to evaluate the prototype system that was implemented using a client-side application that uses the C# code available in Microsoft Azure Emotion API. We have found that the emotions expressed are correlated with the concentration of the students, and devised three distinct levels of concentration (high, medium, and low).

Keywords: Computer vision · Facial expression recognition · Facial emotion recognition · Student concentration

1 Introduction

Information and Communication Technologies (ICT) had become highly prioritized in education in the last few decades. In Europe, the percentage of scholars of the 11th grade in well ICT equipped schools is around 50%, whereas for the 4th to 8th grades are in between 25% and 35% [1]. Additionally, the authors state that "effective professional development can transform positive attitudes and sufficiency in ICT provision into effective and sustained classroom practice".

The advantages and positive aspects of technology usage in education are very high. For example, students nowadays can reach out any data they need for their intended research. They are now able to globalize and meet their colleagues around the world, or even learn new languages. They may virtually attend web seminars that they would not be able to attend in person, due to the lack of money, distances or time constraints.

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"Millennial" is an expression used to appoint generations born after 1980 and have brought out in an era where a huge part of digital technologies has been introduced in daily life [2]. New Millennium Learners (NML) use non-stop ICT and this has a significant impact on the improvement of their mental and cognitive competences. Moreover, according to some analysts, their thinking has also evolved to a different point [2, 3]. Some use the term "grasshopper mind", meaning that their attention and concentration changes quickly from one topic to another [4]. To integrate ICT in schools successfully, significant changes in the central activities are needed [5].

E-learning can be viewed as a new integration of study in schools. It can be implemented in various ways, such as distributed learning, online-distance learning, as well as hybrid learning, and include several adaptations, such as b-learning and m-learning [6, 7]. There are several benefits of using e-learning for both students and teachers. As pointed above, one of these major benefits are the facts that students may have access to the learning materials and contents anytime and anywhere they want [8, 9]. It was demonstrated that enhancement of profit, understanding and capacity is related to the easy access to a vast amount of data [8]. Additionally, during content transaction, students and teachers interact profoundly [8, 10]. Each student may study at his/her own speed and in accordance to his/her level of understanding, and this might raise his/her level of satisfaction with the course and lower the stress.

However, there are two main obstacles to the successful implementation of e-learning: conservatism and lack of habit. The former is intertwined with traditional methods of learning; it is very common the existence of a certain inertia or even opposition to changes. The second is related to the lack of knowledge and training, for the correct use of these technologies. The lack of human contact is another negative aspect that has generated a lot of criticism, and it is considered as an anti-socialization factor and does not promote cultural knowledge, as much as face-to-face teaching/learning, promoting only virtual interaction. Other disadvantages may also be listed [11]: need for a greater effort and motivation of students; greater discipline and self-organization; costs can be high when creating new courses; the creation of courses can be very time-consuming; dependence on the Internet for the provision and transmission of courses; technical difficulties and speed of the Internet can put in question the transmission and promotion of the courses.

There are several factors affecting the concentration of learners. Emotion is a significant part of a learners' mental being, and it has a deep influence on the learners' academic life and his/her cognitive techniques of study and accomplishment [5]. The impact of emotions on accomplishments related to study relies on mutual interactions between self-adjusted study and motivation. If it would be possible to acknowledge how emotions affect motivation and concentration, then it would be possible to improve the educational results [6]. Here, the term emotion implies to a psychological and physiological form of a being, which is individual, efficient, and personal; it is associated with habits, manners, thinking, and sensation [12]. There is a relation between facial muscles movement and specific emotions, such as happiness, sadness, anger, fear, surprise, and disgust [13].

In this paper, we analyze the concentration level of students in a typical e-learning context, using facial emotions analysis using video. Based on this analysis, we try to devise the impact of emotions in that concentration level and reach a concentration level index.

The rest of this paper is organized as follows: Sect. 2 will review some of the works related to this study. In Sect. 3, the proposed system will be explained in detail. In Sect. 4 the experimental results are presented, along with critical discussion of it. Finally, in Sect. 5 this paper will be concluded, and future work directions will be provided.

2 Literature Review

One of the major drawbacks of the current e-learning systems is their inability to keep track of learners' concentration and motivation. One of the most compelling and associated problems is to verify the relevance between motivation and learning [14]. Motivation can be derived from different reasons and it is associated with the learners' emotions, in a bigger scale. Intrinsic task motivation is profoundly connected to the cognitive and emotional characteristics of the assignments. Additionally, emotions may profoundly influence the realization of an assignment, because they can initiate and prolong task motivation [14]. Ekman and Friesen [15] defined the Facial Action Coding System (FACS). It is based on facial muscle changes and can characterize facial actions to express individual human emotions. This system encodes the movements of specific facial muscles called Action Units (AU), reflecting distinct momentary changes in facial appearance.

Visually salient points in facial regions, such as the ends of the eye brows, end of the nose, and the mouth, are called facial landmarks. According to the generation of models, facial landmarks detection approaches can be categorized into three types: active shape-based model and appearance-based model, regression-based model with a combination of local and global models, and convolutional neural network-based methods.

There are seven basic human emotions: happiness, surprise, anger, sadness, fear, disgust, and neutral. Compound emotions consist in a combination of two (or more) basic emotions. Du, Tao, and Martinez [16] introduced twenty-two emotions: the seven basic emotions; twelve compound emotions (most typically expressed by humans); and appall, hate, and awe emotions. According to Du and Martinez [16], facial AU code the forty-six fundamental actions of individual or groups of muscles, typically seen when producing the facial expressions of an emotion. Typically, to recognize facial emotions, first individual AU must be detected and then the system classifies the facial category according to the combination of AU. For example, if an image has been annotated as having AU 12 and 25, the system will classify it as expressing an "happy" emotion (Table 1).

In [18] a human facial expression recognition system is modeled using an eigenface approach. The Hue-Saturation-Value (HSV) color model is used to detect the face in an image. Principal Component Analysis (PCA) is then used to reduce the dimensionality of the eigenspace and then, by projecting the test image upon the eigenspace and calculating the Euclidean distance between the test image and mean of the eigenfaces of the training dataset, the expressions are classified. The authors have tested the

Table 1. Prototypical AU observed in each basic and compound emotion category (adapted from [17]).

Category	AU	Category	AU
Happy	12, 25	Sadly disgusted	4, 10
Sad	4, 15	Fearfully angry	4, 20, 25
Fearful	1, 4, 20, 25	Fearfully surprised	1, 2, 5, 20, 25
Angry	4, 7, 24	Fearfully disgusted	1, 4, 10, 20, 25
Surprised	1, 2, 25, 26	Angrily surprised	4, 25, 26
Disgusted	9, 10, 17	Disgusted surprised	1, 2, 5, 10
Happily sad	4, 6, 12, 25	Happily fearful	1, 2, 12, 25, 26
Happily surprised	1, 2, 12, 25	Angrily disgusted	4, 10, 17
Happily disgusted	10, 12, 25	Awed	1, 2, 5, 25
Sadly fearful	1, 4, 15, 25	Appalled	4, 9, 10
Sadly angry	4, 7, 15	Hatred	4, 7, 10
Sadly surprised	1, 4, 25, 26	–	–

system using a generic dataset and were able to classify five basic emotions: surprise (with an accuracy of 91%), sorrow (78.9%), fear (77.7%), anger (86.2%), and happiness (93.1%).

In [19] a Deep Convolutional Neural Network is used to automatically recognize three facial expressions (happy, sadness and surprise), using a single image. They have used two publicly available facial expression datasets. In [20] the authors use a Faster Regions with Convolutional Neural Network Features for facial expression recognition. They have used a dataset composed by multimodal emotional audio and video data.

Ko [21] presents a review of the research conducted over the past decades on facial emotion recognition based on visual information. He presents the conventional approaches, including a summary of the most representative categories of systems and their main algorithms. Other approaches, such as deep-learning-based approaches and hybrid deep-learning combining a convolutional neural network for the spatial features of an individual frame and long short-term memory for temporal features of consecutive frames, are also presented. A review of some of the publicly available evaluation metrics is also presented, along with a comparison with benchmark results.

Cha and Kim [22, 23] proposed the use of a web-cam to identify the learner movements and determine the duration of the attention. In [22] they analyzed the changes of the following facial features: the front face, face facing downward, the turned face, closed eyes, opened eyes. They state that they "set base values of the face and the eye in the coordinate of extracted feature points" and with that they determined "the focused state and the non-focused state in comparison with base values". However, they do not define or explain how they found the "focused state and non-focused state". They conclude that the learner is focused if his/her face is in "front face" state. They also state that the state of "concentrate" or "non-concentrate" depends on the data analysis of the "learner's face bows or turns from side to side or their eyes open or close". However, do they not explain how this analysis is implemented, nor do they present any degree of concentration. In [23] the authors added a new set features to the work presented in [22]: smile, surprise, sadness, anger, closed mouth, and opened mouth (the shape of the mouth is changed based on pronunciation).

In this work, the concentration was defined as "the situation of the opened eye, the closed mouth and the frontal face", whereas the non-concentration was defined as "the situation of the closed eye, the opened mouth, the downed face, the turned face and facial expressions of emotion". They also state that "if the length value of the eyes is less than the criteria value and the value occur above 0.9 ms" the eye of the learner is closed, implying that he/she is in the state of non-concentration. On the other hand, if the "value occurs under 0.9 ms, it is the blinking eye", implying the state of concentration. They concluded that if a learner is in a non-concentration state, then he/she will have the eyes closed, or the mouth opened, or the face downed, or the face turned or facial expressions of emotion like smile, surprise, sadness, or anger. The concentration state corresponds, once again, to the frontal face with the opened eyes and closed mouth. However, they have implemented these experiments using only Asian people. They do not explain what happens to the basis values if the people's appearance changes (as it is the case of other European of African people, for example).

Yi et al. [24] use gaze tracking to analyze students' learning behavior in front of computer screens. With this information they generate learning status. These statuses may help assess teaching quality. They consider three patterns as the basic actions performed by the eyes during the cognitive process of learning: Scanning, Seeking and Idle. They also concluded that "on idle status, students are not utilizing the information taken in by their eyes on the cognitive level". However, this approach uses only information from the movement of the eyes.

Bosch et al. [25] use computer vision, learning analytics, and machine learning to detect students' affect in the real-world environment of a school computer lab. They were able to detect boredom, confusion, delight, frustration, and engaged concentration in a manner that generalized across students, time, and demographics. They used 19 AU as well as head pose (orientation) and head position. They have used supervised learning, building separate detectors for each affective state, and a two-class approach for each affective state, where that affective state was discriminated from all others (e.g., confusion vs. all other). Their model was applicable 98% of the time. Their approach generalized across days, time of day, gender, and ethnicity. However, the number of used instances was limited for some affective states and the students were all approximately the same age and in the same location.

In [26] the authors developed a reading concentration monitoring system for use with e-books in an intelligent classroom. The system uses three types of sensor technologies: a webcam (to gather eye gaze), heartbeat sensor, and blood oxygen sensor (fingertip oximeter). An Artificial Bee Colony (ABC) optimization approach was used to determine the students' reading concentration rates. As stated by the authors, the results show that the use of the ABC algorithm "can effectively obtain near-optimal solutions".

Other approaches were also used, such as the one proposed by Liu, Chiang, and Chu [27], using Electroencephalography (EEG) signal processing to determine the brain signals which are related to the students' cognitive actions. Although the authors have used five types of brainwaves (α, β, δ, θ, and γ), they concluded that changes in delta activity are related to linguistic acquisition. They also concluded that theta and beta activity have also influence in attentiveness.

Despite the tremendous progress in this research field, there is still need more work about the relation between emotion and concentration. In this paper, we try to establish a new students' concentration index and contribute to the filling of this gape.

3 Proposed System

Figure 1 shows the block diagram of the proposed system. As can be seen, first, the student's actions are captured by the camera. In the second step, the video is analyzed to detect the students' emotions. In the final third step, these emotions are further processed to find the final concentration index.

In the first step, the images of the student's face are captured using a camera. Each frame is then imputed to the Microsoft Azure – Emotion API. The list of emotions predicted by this API include: Anger, Contempt, Disgust, Fear, Happiness, Neutral, Sadness, and Surprise. As suggested by the revision of the literature presented in the previous section, we assume that the "neutral" emotion has the highest concentration (i.e., if a student has the neutral emotion he/she is more focused).

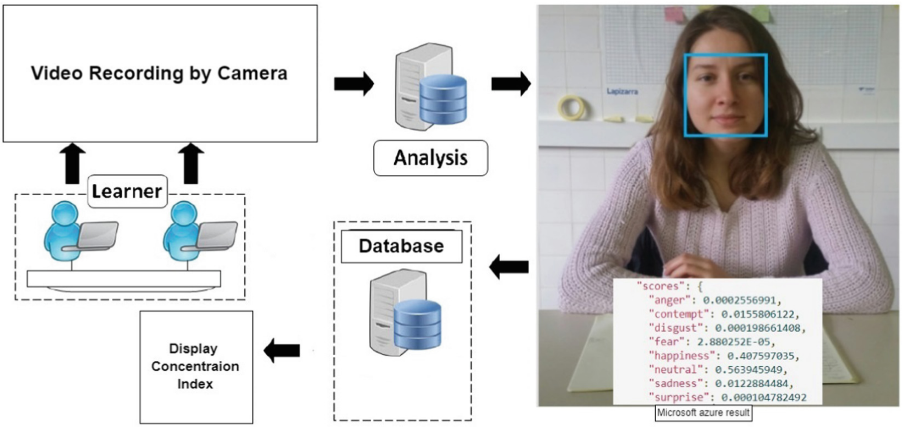

Fig. 1. Block diagram of the proposed system: first, the student's actions are captured by the camera; second, the video is analyzed in order to detect the students' emotions; third, the final concentration index is displayed.

In the next stage, the video images are passed to the Microsoft Azure – Emotion API. The output of this API is given in the form of a JSON file with the confidence value for each emotion. The application was developed using C# code, and the kernel of the API was modified according to our specific needs.

In the final step, the concentration index is calculated. In this step, first, the emotion confidence values returned by the Microsoft Azure – Emotion API are stored in a database. Then, for each frame, these values are weighted to give the concentration index, using the following weights: Anger – 0.1, Contempt – 0.1, Disgust – 0.1, Fear – 0.1, Happiness – 0.2, Neutral – 1, Sadness – 0.1, and Surprise – 0.1. These weights were found by trial and error. The resulting concentration index has sharp variations, from frame to frame, as can be seen in Fig. 2 (blue line, marked as "original"). Finally, to remove some of these sudden fluctuations of the concentration index (trying to make it smoother), a sliding window low-pass filter (average filter), with a window size of 25, is applied to these values of the concentration index. The resulting final concentration index is show in Fig. 2 (red line, marked as "filtered").

4 Experimental Results

We have used a Nikon D3100 camera to record a color 1-minute video, using 3 channels × 8 bits/channel (24-bit RGB), at 25 frames per second (fps), with a resolution of 3072 × 4608 pixels, and saved it using the AVI format.

After the video was captured, the frames were extracted so that it can be uploaded to the Microsoft Azure – Emotion API for the analysis of emotions.

After that, Microsoft Azure – Emotion API returns the concentration values, and these values were stored in the database. These values are then further processed, and the resulting concentration index is obtained. Figure 2 shows the evolution of the resulting concentration level over time. In the original (blued line), there are sudden variations in this index, from frame to frame. These variations may be artificially caused by small lighting changes, or any other non-desired changes. In real life, we

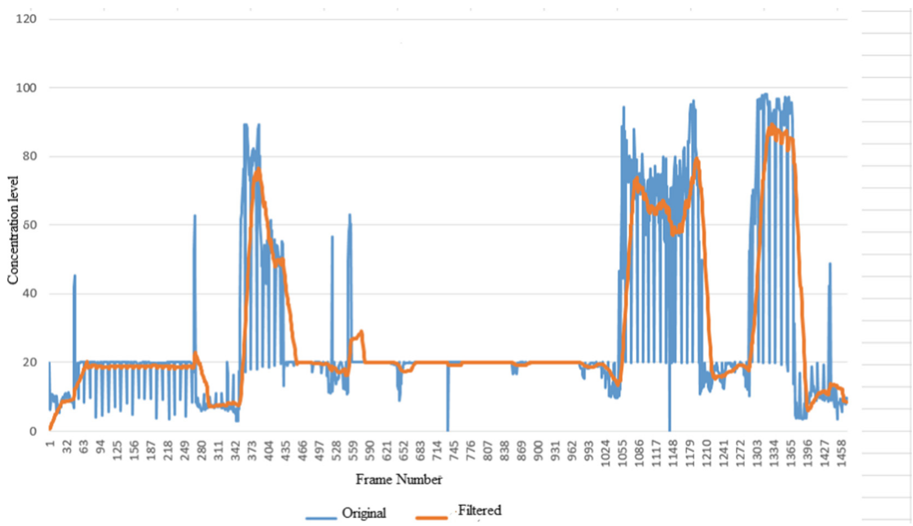

Fig. 2. Plot of the evolution of the concentration level over time. The "original" line corresponds to the values of the concentration index directly returned by the Microsoft Azure – Emotion API, and the "filtered" (red) line represents the final concentration index, achieved after applying a sliding-window low-pass filter with a window size of 25. (Color figure online)

know that it is impossible to have such drastic changes from frame to frame. So, to have a smoother signal (index), corresponding to more realistic changes in the student's emotions, we have used a sliding-window low-pass filter (average filter), with window size of 25 (this value was achieved by trial and error). The resulting final concentration index is plotted in red, in Fig. 2. Here, we can clearly identify three different concentration levels over time: high, medium and low.

4.1 High Concentration Level

We define the "Highly concentrated level" as the level in which the student emits a neutral emotion pose, i.e., the resulting classification set of emotions returned by the Microsoft Azure – Emotion API is almost zero for any other emotion besides the neutral emotion. As stated before, we borrowed this idea from the literature review presented in Sect. 2.

This state is clearly present in the final concentration index plot of Fig. 2, from frame 343 to frame 373, and from frame 1055 to frame 1117 and from frame 1304 to frame 1395. Note also that, as expected, these values correspond to the heights values, the peaks, in the plot.

4.2 Medium Concentration Level

The "Medium concentrated a level" is defined as the level in which the "peak" value is moderate. In this level of concentration, the student expresses other different emotions besides the neutral emotion.

In the case of Fig. 2, for example, we can see that the frames between 1148 and 1179 are in this level of concentration (Medium Concentration level).

4.3 Low Concentration Level

In "Low Concentrated level" the student expresses several different emotions, but never the neutral emotion. This will correspond to the lower valleys in the plotted signal. In this level, due to different external factors, the student does not pay attention to the contents being presented/taught. The delivered material will not reach its destination. The ultimate goal will be the removal of this level, and, hence, improve the relationship between the learner and the learning material. The learning system will improve if we are able to remove this level.

In the case of Fig. 2, for example, we can see that the frames between 0 and 342, and from frame 466 to frame 1055, are in this level of concentration (Low Concentration level).

5 Conclusion

In this paper, we proposed a system to check the students' concentration in an e-learning context, by analyzing the student's emotions. The proposed system has three main steps: first, the student's actions are captured by the camera; second, the video is analyzed to detect the students' emotions; third, the emotions are further processed to find the final concentration index.

The system will help to fill the gap between the learner and the learning material/concepts/skills, during the content delivery process.

This index can be used by the e-learning system in real time. By using this index, the e-learning system can automatically adapt the contents, according to the student's concentration level, so that the learning process will be more efficient.

However, because a 2D-based analysis has difficulties handling large variations in pose and subtle facial behaviors, recent researches have considered 3D facial expressions to better facilitate an examination of the fine structural changes inherent to spontaneous expressions. We want to merge this possibility with the information retrieved with the help of other sensors, such as heart rate, EEG signals, and oxygen level, among other.

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Telepresence Robots in the Classroom: The State-of-the-Art and a Proposal for a Telepresence Service for Higher Education

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Abstract. In this work we reviewed the current state-of-the art regarding the usage of robots, in particular telepresence robots, on educational related activities. We also researched the current consumer and corporate grade telepresence robotic equipment and tested three of these devices. Lastly, we reviewed the problem of disabled students, including students with special education needs, which fail at accessing and staying on higher education. One of the reasons for such problem is the impossibility to physically attend all the classes due to temporary or permanent limitations. As a conclusion of this work, and considering the ongoing positive cases with robotics and the current equipment availability, we propose the creation of telepresence services on the higher education institutions as a solution for those students that can't attend classes.

Keywords: Telepresence robot · Higher education · Disabled students

1 Introduction

This work presents a proposal for the creation of telepresence services on higher education institutions as a solution to the problem of the very high rate of disable students (including students with special education needs) that can't access higher education or drop out shortly after registration. To base the proposal, we reviewed, in Sect. 2, the current usage of robotics in education, for which we present several positive case and authors opinions, as well as the current line of robotics products which, as we show in Sect. 3, are available to the consumer market worldwide. On Sect. 4.1 we present the current problems and related data regarding higher education and students with disabilities, for which we conclude that telepresence can indeed be a solution and that the time is write for it's adoption.

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2 Robotics in Education

At the beginning of the new millennium, the world faced big changes of infrastructures led by the quick growth of technologies, multimedia and robotics. Many countries have world class infrastructures in Information and Communication Technology (ICT), and so they started instigating profoundly the development of a variety of educational programs [1].

Conti [2] affirms that the evolution of the technology and the achievements of these researches boosted the area of robotics that has resulted in a fast grow of possible applications in the everyday life of the common people, like facilitating the children education in a school. For Robins [3], robots, virtual environments and other computer-based technologies are increasingly being applied in therapy and education. Han go even further [4]. For them the use of robotics in education is on the rise, with the robot industry now recognized as one of the most important key future industries throughout the world. Like the other authors, Cooper said that robots have found widespread application in industry and are beginning to find applications in diverse roles like the education [5].

For Nourbakhsh, robots have the potential to excite and inspire children and adults [6]. They make a fascinating hybrid-dynamical system for study and comprehension and an excellent facilitator for the study. Conti reaffirms that robots have great potential for sound pedagogic reasons within education at all levels [2].

The education systems can now take advantage of these new opportunities presented by the evolution of robots. Conti affirms that the research in robotics has made available numerous possibilities for further innovation in the education of children, especially in the rehabilitation of those with learning difficulties and/or intellectual disabilities. They provide opportunities for making accessible, for a wide range of disabled students, practical elements of the curriculum.

One of the well-known advantages of the robots in education is their ability to interact with humans. For Conti, robots create opportunities not only to learn from a three-dimensional inanimate object, but also to learn through interaction with other human beings. Houwen [7] adds that this has enabled robots to help with a variety of human-like functions, as well as to aid with the goal of improving social skills in individuals with disability.

Benitti [8] goes even further. They suggest that educational robotics can act as an element that enhances learning, if appropriately used. Dockrell [9] add that robotic assistants have the potential to overcome concerns about the physical effects of children's use of computer-based tools.

These ideas lead us to consider the usage of robots in a classroom. But before entering in this area, some concepts must be defined. Karna-Lin [10] has defined that educational robotics includes concrete tools and physical artefacts that can be used to help student learning. The same authors have defined that educational technology refers to technology tools and software that have been created to support learning and teaching. So, they conclude that educational robotics can reveal new hidden potentials and skills that students with individual needs may have. Educational robotics also allows the use of different learning styles and use of many senses, which is essential for students with individual needs.

For Sharkey [11], robots in the classroom are being used in four basic ways: robot as classroom teacher, robot as companion and peer, robot as care-eliciting companion, and telepresence robot teacher.

Karna-Lin led us to a very interesting question. Can Robots Teach?

Cooper affirm that educational applications for robots hold promise for students or pupils with disabilities in two main ways:

- Navigation: It should have an easy-to-use interface; smooth movement; variable speeds; obstacle indicators.
- Camera should show a wide angle and allow zooming.
- Audio should be able to receive wide-range input.
- Output should be loud enough to be heard by an audience.
- Video display should show the user's face close to actual size.
- Robot height should be close to human-like sitting and/or standing.
- It should be packable (able to be dis-assembled; lightweight).
- It should be robust and durable.
- It should be affordable.

Robins [3] present a study where an investigation has been taken from a small minimally expressive humanoid robot KASPAR. This robot can assume the role of a social mediator - encouraging children with low functioning autism to interact with the robot, to break their isolation and importantly, to facilitate interaction with other people.

According to this study the usage of the robot KASPAR is an example of how (relatively) simple, minimally expressive robots can facilitate interactive 'social' games that benefit the children and the wider social environment. It also concludes that this robot is an example of how low-tech solutions, appropriately designed for and adapted to the context of use and the needs of its users, can contribute to social education.

Han [4] presented a study that compares the effects of non-computer based (NCB) media (using a book with audiotape) and Web-Based Instruction (WBI), with the effects of Home Robot-Assisted Learning (HRL) for children.

As expected the HRL showed the highest level of interest to the children. They also conclude that the HRL was superior in promoting and improving children's concentration, interest, and academic achievement. In addition, the children felt that a home robot was friendlier than other types of instructional media. So, this study suggests that a home robot as a tutor for children is most useful and could become a new educational media.

Robins [3] investigated in what ways and how a robot can assume the role of a social mediator - encouraging autistic children to interact with the robot, with each other and with co-present adults.

The study showed that with the robot being the focus of attention, it mediated interactions between the autistic children and other people – children and adults. They showed that this role of the robot as a social mediator can be further enhanced when the robot is used as a tool in the hand of an experienced experimenter/operator/therapist.

In their study, Kronreif [18] describe one possible contribution of selected robotics technology and automation for making toys available to children with severe physical disabilities. The study aimed to analyses how children with physical disabilities play in comparison with normal children.

With this study the authors have developed a first prototype system that uses three robots for playing with LEGO™ bricks. They concluded that physical disabled children should get improved access to toys to play with and – besides learning - to simply have great fun. Up-to-date technology can be a useful tool to realize adapted toys for severe physical disabled children.

In the current days it's possible to identify lots of examples of robots already developed and commercialized with the goal of helping the students with special needs. For example, the UTAD University has already bought some of these robots. Currently they are used in a project with the nursing school. The robots used for this project are: Double 2, Beam enhanced and PadBot U2.

Many others educational robots can be found in all world. Here some of the most recent examples of their usage.

The Holmans Foundation for Autism, represented by CEO Anthony Trujillo, donated three robots to students in the homebound program at Aztec Complex. These robots allow students to virtually attend events at their school while in the homebound program [19].

The Michigan State University is using educational robots in the most effective way to teach remote students. Rather than being just one of a dozen faces carried over a group video call like Skype or Google Hangouts, the use of a robot proxy gives every student mobility and individuality [20].

The Duke University School of Nursing is using a telepresence robot, named JaMMeR to steers the simulation room of a treatment of a pediatric patient. The provider is hundreds of miles away and logged into the robot [21].

The Wild Rose School Board is using the tele-presence robot's unit to offer classes they currently don't offer to students by paying for them through their partnered virtual schools. They offer the opportunity for students and staff to take a class or attend a conference remotely from the high school [22].

3 Three Telepresence Robots

The following three robots are common consumer grade equipment, currently available at INESC TEC and UTAD, used for HCI research activities. They were chosen due to their diversity in features, price range and business model.

3.1 The Beam

The Beam, by Suitable Technologies [23], displayed on Fig. 1, is part of a high-end line of equipment, particularly suited for corporate collaboration scenarios by letting the user to roll up to his colleagues to troubleshoot, review artwork, or give a killer presentation. Beam aims to transform “the way individuals, teams and companies interact and work together. Professional relationships are stronger, corporate culture more cohesive, and creative projects more successful”.

Fig. 1. The Beam telepresence robot.

To use the equipment, the user must install an app and drive the Beam from a smartphone, tablet or desktop. The fully integrated system is compatible with Windows, OSX, Android (phones and tablets made after January 2014), and iOS (iPhone 5s and newer) devices. The device was built by Suitable Technologies from the ground up with proprietary software and algorithms. It uses industry-standard technology such as TLS/SSL, AES-256, and HMAC-SHA1, and encrypts all communication to ensure private and secure calls.

3.2 The Double 2

The Double 2, by Double Robotics [24], as displayed on Fig. 2, is a self-balances equipment that relies on an IPAD and a camera and audio kit to provide the telepresence robot full features. It is very well marketed with very well-presented usage cases in several areas, e.g., education, business, health, etc. The business model used by Double Robotics includes a fleet management option and other corporate support features that suggests an evolution to a telepresence subscription service model. Technically, the equipment most relevant features are the two heels drive and stability as well as the security and privacy features (end-to-end 128 bit AES Encryption).

Fig. 2. The Double 2 telepresence robot.

3.3 PadBot U2

PadBot U2, as displayed in Fig. 3, is part of an equipment line series, produced by InBot Technology [25], and targeted for simple usage scenarios. The equipment fully relies on a tablet for all the features, except wheel drive. The two main distinctive factors are: the ability to fold the display support structure, thus allowing easy storage and transport; and the ability to tilt the table position, providing a look up and down feature. On other manufactures equipment's the tilt feature is replaced by the usage of two cameras covering the necessary perspectives.

Fig. 3. PadBot U2 telepresence robot.

4 A Proposal for a Telepresence Service for Higher Education Students

This proposal advocates the usage of telepresence robots to enable students with temporary or permanent special needs to remotely attend classes. Higher Education Institutions (HEI) could provide this alternative access medium as a service, targeted at those students in need. In a previous work, we assessed the current scenario of students with special needs and the barriers to higher education, which we resume in Sect. 3.1.

4.1 Higher Education for Students with Disability and/or Special Education Needs

In the European Union (EU) there are about 80 million people affected by some sort of disability and in Portugal alone that number is about 1 million people [26]. In the EU in general, and particularly in Portugal, opportunities are unevenly distributed between people with disabilities and the general population. Throughout history there have not been enough practices and policies to address this problem in order to cancel and repeal the unevenness, social injustices and exclusion that affect the disabled population within the different social realms. One of those areas is education, where this problem is well present from the beginning in terms of access to education, as well as later, in the dropout rate when attendance requirements are not met [27].

The Portuguese state has subscribed to the United Nations Standard Rules on the Equalization of Opportunities for Persons with Disabilities [28], the Salamanca Declaration [29] and the International Convention on the Rights of Persons with Disabilities [30]. These agreements are international juridical instruments that bind the government to assure dignity in the life of those with a disability, including equal rights and opportunities to access education for all disabled children, teenagers and adults.

The number of students with Special Education Needs (SEN) registered in schools has grown in the last years, although in Higher Education (HE) it is still a very small percentage of the population when compared with the total number of students in Higher Education Institutions (HEI). The Workgroup to Support Higher Education Students with Disability (WSHESD), hosted by the Portuguese Ministry of Science, Technology and Higher Education (MCTES), conducted a national survey regarding the support provided to students with SEN in HE. According to this survey, the percentage of students with SEN in Portuguese HEI is about 0,36% and only about 1% of the high school students with SEN will attempt to continue their studies in a HEI [31]. These numbers reveal a very dramatic scenario.

From a technical perspective, several projects have been developed to assure disabled students physical access to HE classes and digital access to the contents [32–39]. Unfortunately, these initiatives have a limited impact, as different types of disabilities need specific and integrated approaches, or the solutions must be broader then the technical perspective. Another important aspect is related to the adoption of technology, in particular systems design and user motivation as we have argued in other projects, in the fields of healthcare and rehabilitation [40–43].

Currently, there is a lack of answers and solutions to allow SEN students to attend HE in an inclusive and equal manner.

Consequently:

1. The majority of the students with SEN will not apply to HE;
2. A significative number of students with SEN that get accepted into a HEI will drop out shortly after;
3. There is a very tiny percentage of students with SEN attending HE. Therefore, it is of the utmost importance to create and adopt solutions that might encourage and enable students with SEN or any other permanent or temporary disability to attend HE.

Due to several temporary or permanent reasons, a significant number of SEN students, as well as a small number of regular students, are unable to attend classes in the same terms as their colleagues.

For students who cannot be physically present in the classroom, telepresence and remote class systems can provide features which allow these students to watch the classes, to access the content of the classes, as well as to communicate and interact with the professors and classmates. The usage of telepresence robots can further enhance this concept by allowing the telepresent student to watch, listen, move, join, and interact in a more realistic and independent way [12].

4.2 The Telepresence Robot in the Classroom as a Service

The implementation of the telepresence robot in the classroom as a service should be a straightforward task in which the telepresence robot equipment should be faced as any other electronic equipment currently used for class teaching, e.g., laptop, video projector, etc.

The whole process for a student to have access to the service could be as simple as a three step:

1. Require the telepresence service.
2. Have a profile check and authorization by the faculty.
3. To instruct the instruct the staff, responsible for the electronic equipment management, to install the equipment on the rooms and schedules required and authorized.

Considering that HEI already have services or structures devoted to deal with disabled students, this service would be managed by such services. A special care should be taken because, as the numbers of Sect. 3.1 show, SEN students are a very fragile population which might be easily excluded by a poor service.

5 Conclusions

In this work we focused on assessing the current state of: the usage of robotics in education; the current consumer and corporate grade telepresence equipment; the problem of disable students to access higher education. On these three issues, we can conclude that:

1. There is an ongoing trend to use robotic technologies for education and particularly in the context of class teaching.
2. There is telepresence robot equipment able to boost remote communication and collaboration, currently available to the consumer market and corporate market. This equipment is already in use on several areas, e.g., education, health, etc. although remain as novelty for early adopters.
3. There is a serious problem regarding the access of disable students to education, which must be addressed.

We think that the problem stated in 3 will have to be addressed with multiple perspectives and solutions. The research suggests that the proposal to use telepresence robots, as an alternative option for disable students to access classes, particularly, when there aren't other reasonable options, might be a good contribution to make higher education more appealing to those finishing secondary education as well as to those already on higher education but failing to attend classes due to their disability.

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Big Data in Education and Learning Analytics

Prediction of Students' Graduation Time Using a Two-Level Classification Algorithm

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Abstract. During the last decades, higher educational institutes have managed to accumulate a large volume of data about their students' characteristics and performance. Machine learning techniques offer a first step and a helping hand in extracting useful information from these data and gaining insights into the prediction of students' progress and performance. In this work, we present a two-level classification algorithm for predicting students' graduation time. The proposed algorithm has two major features. Firstly, it identifies with high accuracy the students at risk of not completing their studies; secondly, it classifies the students based on their expected graduation time. Our preliminary numerical experiments indicate that the proposed algorithm exhibits reliable predictions based on the students' performance in their courses during the first two years of their studies.

Keywords: Educational data mining · Machine learning · Two-level classification algorithm · Student academic performance

1 Introduction

Higher education constitutes a significant and critical factor in human resources development, increasing people's knowledge and competencies and ensuring nations' economic prosperity. The main objective of a higher education institute and one of its biggest challenges is to provide quality education to its students. In 2001, the *National Research Council report* [7] illustrated the immediate need to develop innovative methodologies to assist higher institutes, which will further improve the quality of their studies, facilitate students' timely graduation and limit their dropout. To achieve a higher level of studies' quality, there are three

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main key aspects: the first two lay emphasis on refining teaching and knowledge acquisition methods, while the third one concerns the development of efficient systems for monitoring students' progress and identifies key aspects of their success.

An enduring issue in higher education is student retention of successful graduation [2]. As the cost of higher education (fees, living expenses, etc.) has exploded over the past decade, prolonged graduation time consists a crucial factor in discouraging students ultimately leading them to dropout. In fact, recent studies show that a minority of students have succeeded to complete a four-year bachelor program on time [10,25,26]. Some of the causes of slow student progress are the inability to register for required courses, credits lost in transfer and remediation sequences that do not work.

Therefore, a crucial step towards effective intervention is to develop a system which can continuously keep track of students' academic progress and accurately predict their graduation time. The ability to accurately predict students' future performance is considered essential for effectively carrying out necessary pedagogical interventions to ensure students' on-time and satisfactory graduation. By analyzing students' progress, appropriate actions and strategic programs could be well planned in an institution in order to decrease the students' mean graduation time and limit dropout.

Although the prediction of students performance in a course has been extensively studied in the literature [3,16–18,21,22,28,29], the early prediction of their graduation time is a significantly different task which faces new challenges. This is due to many factors: firstly, students attend many courses during their studies, but not all courses are equally informative about their graduation; secondly, students differ in terms of knowledge backgrounds and specializations, as well as in the sequence they choose their courses; finally, the predictions need to be made based not only on the most recent students' accomplishments, but also on the evolution of their progress. Therefore, the application of machine learning techniques is considered essential, offering a first step in extracting useful and novel information from these students' records in order to gain a deeper insight in the prediction of students' progress and performance.

The main objective of this research is to predict students' graduation time, putting emphasis on the identification of students who are likely not to complete their studies within six years or dropout. Specifically, we are dealing with the following main tasks:

- Predict students at risk of not graduating within 6 years of studies.
- Classify the students' based on their graduation time.

Nevertheless, the development of an accurate prediction model is a very attractive and challenging task (see [3,18,21,22] and references therein). The task of predicting students' graduation time becomes very complicated by the expanding volume of data, from the increasing student enrollments and by the continually shifting performance during their studies. Generally, educational datasets are imbalanced, hence standard learning algorithms face inability to detect a pattern based on the correct distribution governing the classes of dataset, frequently exhibiting an unacceptable error rate for the minority classes. Furthermore, the difficulty to distinguish between noise and rare cases is also responsible for poor performance on the minority classes [13–15].

In this paper, we present a model for predicting the years taken for a student to complete a bachelor's degree study. Our prediction model is based on a two-level classification algorithm, which accurately classifies the students based on courses' characteristics, students' demographic information and their performance in courses during the first two years of their studies. The early prediction of students' future progress enables the allocation of proper actions to support them and eliminate problems causing late graduation or dropout.

The remainder of this paper is organized as follows: Sect. 2 presents a survey of recent studies concerning the application of data mining in education. Section 3 presents a detailed description of the data collection and data preparation used in our study and the proposed two-level classification algorithm. Finally, Sect. 4 presents experimental results while Sect. 5 sketches concluding remarks and future work directions.

2 Related Studies

The development and adoption of machine learning systems for predicting students' performance has gained popularity during the last decades, addressing many issues and problems in the educational domain and providing useful outcomes about the learning process. Numerous research studies have been conducted to predict students' academic performance either to facilitate degree planning or to determine students at risk. Romero and Ventura [21,22] and Baker and Yacef [3] have provided some extensive reviews of different types of educational systems and how data mining can be successfully applied to each of them. More specifically, they described in detail the most accurate models utilized for the prediction of students' performance available in the literature and summarized the diverse factors that influence the performance of students. Along this line, Peña-Ayala [18] presented a review aiming to preserve and enhance the chronicles of recent educational data mining advances and developments and analyze the outcomes produced by a machine learning approach.

Musso et al. [16] have proposed an artificial neural network approach for predicting general academic performance of university students identifying the differential contribution of participating variables using cognitive and non-cognitive measures of students, together with background information. The results showed that neural networks can achieve higher accuracy rate than traditional methods such as discriminant analysis.

Nagy et al. [17] developed an intelligent student advisory framework to improve the success rate of the first year university stage utilizing machine learning techniques. This framework can be used to provide pieces of consultations to a first year university student to pursue a certain education track where he/she will likely succeed in, aiming to decrease the high rate of academic failure among students. The framework acquires information from the datasets which store the academic achievements of students before enrolling to higher education together with their first year grade after enrolling in a certain department. After acquiring the relevant information, the intelligent system utilizes both classification and clustering techniques to provide recommendations for a certain department for a new student. Additionally, they presented a case study to prove the efficiency of the proposed framework. Students' data were collected from Cairo Higher Institute for Engineering, Computer Science and Management department, during the period 2000–2012.

Saa [24] explored multiple factors which theoretically affect students' performance in higher education and concluded to some interesting results. In particular, he showed that the students' performance is not totally dependent on their academic efforts; there are many other personal and social factors that have equal or greater influences as well. Moreover, he developed a qualitative model that classifies students and predicts their performance.

Yasmeen et al. [28] proposed a prediction model for students' academic performance and studied the identification of the courses which highly influence and affect low academic performance. Their study was based on records of 100 graduates from the Information Technology department of King Saud University. Their primary goal was to explore the high potential of data mining applications for university management, referring to the optimal usage of data mining methods and techniques to the collected historical data. Their experiments indicate that reliable predictions can be achieved based on the performance of students in second year courses.

Along this line, Yassein et al. [29] utilized machine learning and data mining techniques to deeply analyze students' data and identify features affecting student performance in selected courses in Najran University in Saudi Arabia. More specifically, they studied the relationship between both practical work and assignments in several courses and their success rate. Their results revealed the strong relationship between these factors; in addition, it was found that a large number of given assignments acts negatively on course academic performance.

Xu et al. [26] developed a model that predicts student performance in degree programs using a novel machine learning method based on students' progressive performance states. Their proposed method adopts a latent factor model-based course clustering method developed to discover relevant courses for constructing base predictors while an ensemble-based progressive prediction architecture was developed to incorporate students' evolving performance into the prediction. The dataset contained 1169 undergraduate students over three years from Mechanical and Aerospace Engineering department at UCLA. Their results showed up the effectiveness of their proposed method achieving superior performance to benchmark approaches.

3 Research Methodology

The primary goals of the present research are the accurate and early identification of the students who are at-risk of not completing their studies within six years and the accurate classification of students who have successfully graduated. We have adopted a two-stages methodology, where the first stage concerns data collection and data preparation, while the second one deploys the proposed two-level classification algorithm.

3.1 Dataset

We have collected 282 student records over four years (2010–2013) from the School of Health & Social Welfare of Technological Institute of Western Greece. The dataset consists of demographic information as well as information of the students' performance in courses of the first two years of their studies. Notice that the Bachelor's degree program consists of four (4) academic years (eight semesters). Each record comprised 127 variables divided in two groups: the "*Demographic-based group*" and the "*Performance-based group*".

Table 1. Demographic-based group attributes

Attribute	Values
Genger	Male/female
Age	Integer
Home location	Nominal
High school type	Technical/general/evening

Table 2. Performance-based group attributes

Attribute	Values
Type of course	Core/laboratory/clinical
Number of times examined	Integer
Final grade in the course	Integer

The Demographic-based group represents attributes concerning students' gender, age, home location and type of high school, as presented in Table 1. The reason why most researchers utilize students demographic information such as gender is because male and female students exhibit different styles of learning process [5].

The Performance-based group represents attributes concerning courses characteristics and students' progress in several courses. More specifically, the Bachelor's program includes 41 courses of which twenty five (25) are core, twelve (12) are laboratory and four (4) are clinical courses. For each course, we register the type of course (core/laboratory/clinical), the number of times the student was examined in the first three years of his/her studies and the final grade (Table 2).

It is noted that in case, the student has not successfully passed the course, the grade assigned is -1.

Finally, the students were classified utilizing a four-level classification scheme, based on the years needed to complete their studies, namely {*4 years*, *5 years*, *6 years*, *Fail*}.

3.2 Two-Level Classification Algorithm

Subsequently, we present our proposed novel two-level classification scheme aiming to achieve the highest possible efficiency and efficacy. We recall that two-level classification schemes are heuristic pattern recognition tools that are supposed to yield better classification accuracy than single-level ones at the expense of a certain complication of the classification structure [4,11,12,27].

An overview of our classification algorithm is depicted in Fig. 1 while a high level description of the training process of our two-level classifier is presented in Table 3. On the first level of our classification scheme, we utilize a classifier to distinguish the students who are likely to "*Graduate*" or "*Fail*". More analytically, this classifier predicts whether the student will manage to complete his/her studies within 6 years. In the rest of our work, we refer to this classifier as A-level

Table 3. Two-level classifier

Input: D − Initial training dataset.
C_A − User selected A-level classifier.
C_B − User selected B-level classifier.
Output: Use trained two-level classifier to predict class labels of the test cases.

/* Initialization phase */
Set $D_A = \emptyset$ and $D_B = \emptyset$.
for each $(x, y) \in D$ do
    if ($y ==$ "Fail") then
        $D_A = D_A \cup (x, y)$.
    else
        $D_A = D_A \cup (x,$ "Graduate"$)$.
        $D_B = D_B \cup (x, y)$.
    end if

/* Training phase */
Train classifier C_A on dataset D_A.
Train classifier C_B on dataset D_B.

Remarks: For each instance (x, y) in the dataset D, x stands for the vector of attributes while y stands for the output variable, namely $y \in$ {"4 years", "5 years", "6 years", "Fail"}

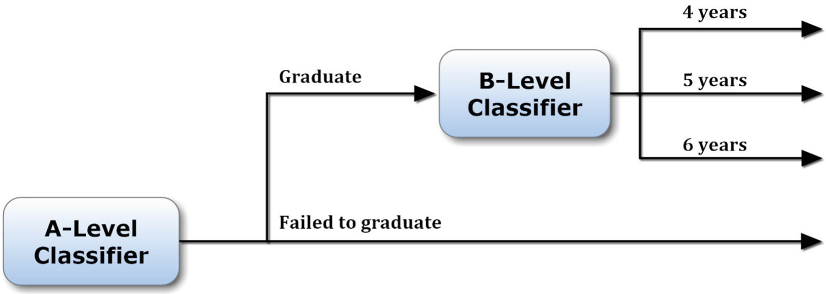

Fig. 1. An overview of the two-level classifier

classifier. Clearly, the primary goal of the classifier in this level is to identify the students' who are at-risk of not completing their studies. In case the verdict (or prediction) of the A-level classifier is "*Graduate*", we use a second-level classifier to conduct a more specialized decision and distinguish between "*4 years*", "*5 years*" and "*6 years*" to finish his/her studies. We refer this classifier as B-level classifier.

4 Experimental Results

In this section, we present a series of tests conducted to evaluate the performance of the proposed two-level classification scheme utilizing the most popular and frequently used classification algorithms as A-level and B-level learners.

Naive Bayes (NB) algorithm was the representative of the Bayesian networks [8]. The Back-Propagation (BP) algorithm with momentum [23] was representative of the artificial neural networks while from the support vector machines, we have selected the Sequential Minimal Optimization (SMO) algorithm [19]. From the decision trees, C4.5 algorithm [20] was the representative in our study and RIPPER (JRip) algorithm [6] was selected as a typical rule-learning technique since it is one of the most commonly used methods for producing classification rules. Finally, 10NN algorithm was selected as instance-based learner [1] with Euclidean distance as distance metric.

The implementation code was written in JAVA using the WEKA Machine Learning Toolkit [9]. The classification accuracy was evaluated using the stratified 10-fold cross-validation i.e. the data was separated into folds so that each fold had the same distribution of grades as the entire data set.

To evaluate the performance of the proposed classification algorithm, we consider the following four performance metrics.

$$A_{NG} = \frac{\text{number of students correctly predicted Not to Graduate}}{\text{total number of not graduated students}}.$$

$$A_{G} = \frac{\text{number of students correctly predicted to Graduate}}{\text{total number of graduated students}}.$$

$$A_{CGT} = \frac{\text{number of graduated students Correctly predicted their Graduation Time}}{\text{total number of graduated students}}.$$

$$A_C = \frac{\text{number of Correctly classified students}}{\text{total number of students}}.$$

The first two metrics evaluate the performance of A-level classifier, the third metric evaluates the performance of B-level classifier while the last metric evaluates the overall performance of the proposed two-level classification scheme. Our aim is to find which learner is best suited for A-level and B-level for producing the highest performance.

Table 4 presents the performance evaluation of A-level and B-level classifiers. Table 5 presents the performance of the proposed two-level scheme utilizing various learners as A-level and B-level classifiers. Notice that the highest classification accuracy is highlighted in bold. Additionally, a more representative visualization of the classification performance of the compared classifiers for each performance metric is presented in Figs. 2, 3, 3, 4 and 5.

Table 4. Accuracy of A-level and B-level classifiers

Classifier	A_{NG}	A_G	A_{CGT}
NB	63.04%	75.38%	60.80%
BP	60.87%	98.99%	66.33%
SMO	63.04%	96.98%	68.84%
C4.5	52.17%	97.99%	**77.39**%
JRip	50.00%	95.48%	76.88%
10NN	**84.78**%	**98.99**%	75.38%

Table 5. Two-level classifier classification accuracy

		B-level classifier					
		NB	BP	SMO	C4.5	JRip	10NN
A-level classifier	NB	49.27%	49.70%	51.73%	59.10%	57.90%	55.87%
	BP	60.37%	64.88%	66.95%	73.88%	73.52%	72.28%
	SMO	60.75%	64.08%	65.72%	73.05%	73.50%	71.05%
	C4.5	57.90%	62.83%	64.90%	72.23%	71.87%	70.23%
	JRip	56.72%	61.65%	64.12%	70.25%	71.08%	69.87%
	10NN	64.82%	69.73%	71.80%	**78.73**%	76.75%	77.13%

Clearly, 10NN illustrates the best performance as A-level classifier, since it exhibits the highest accuracy of correctly identifying students who managed to graduate (or not), within 6 years. Moreover, C4.5 reports the best performance as B-level classifier, illustrating the highest percentage of correctly classified students who have successfully graduated, closely followed by JRip.

Figures 2, 3 and 4 present the classification performance of the compared learners, relative to each performance metric while Fig. 5 presents the average

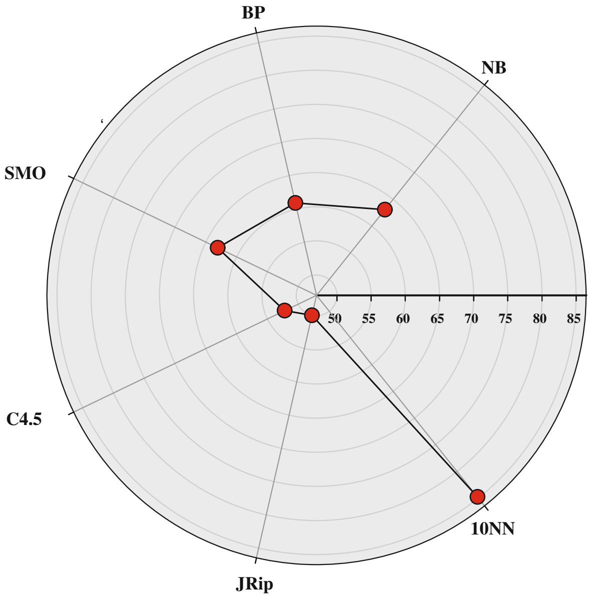

Fig. 2. Radar plot for performance comparison relative to the performance metric A_{NG}

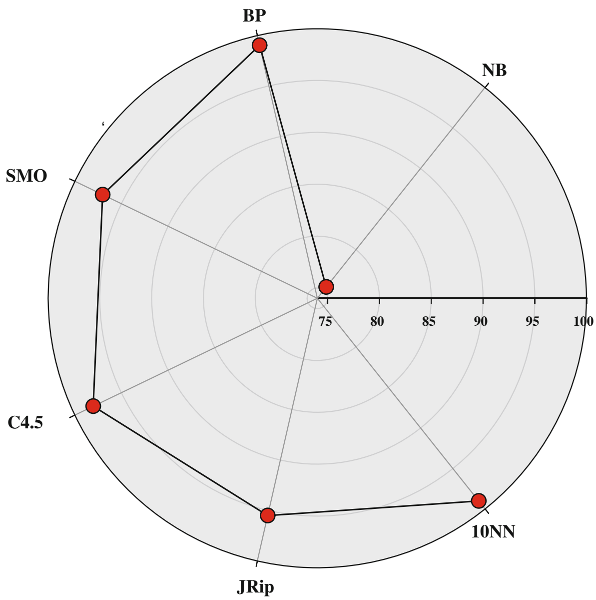

Fig. 3. Radar plot for performance comparison relative to the performance metric A_G

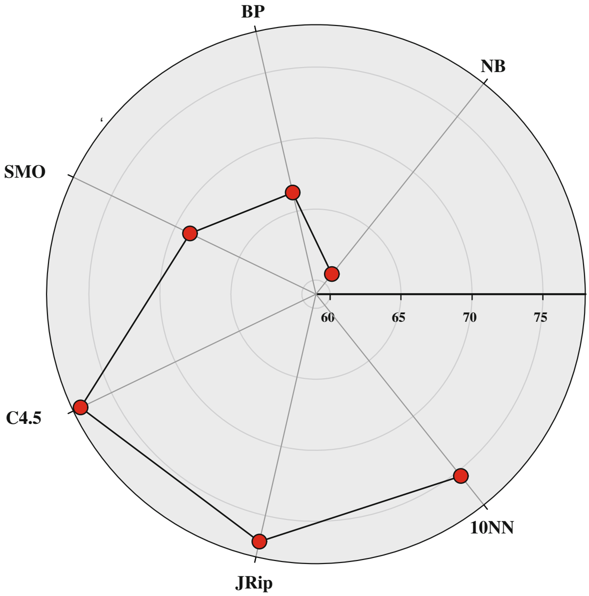

Fig. 4. Radar plot for performance comparison relative to the performance metric A_{CGT}

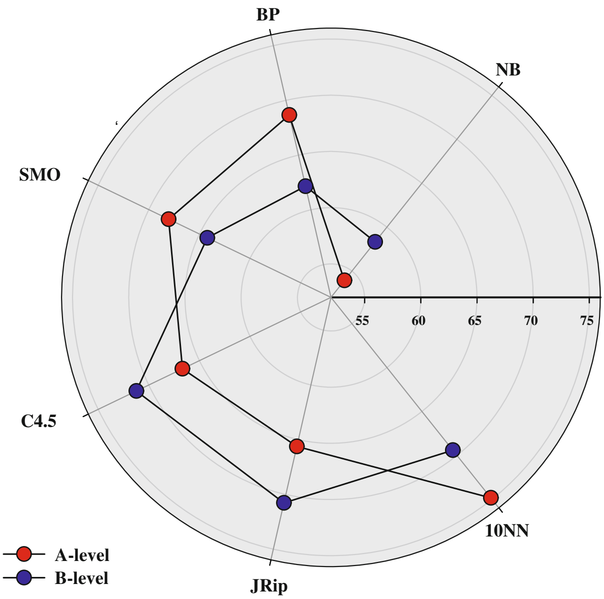

Fig. 5. Radar plot for performance comparison relative to average performance of A-level and B-level classifier

performance of A-level and B-level classifiers. The interpretation of Figs. 2 and 3 reveal that 10NN reported the highest average classification accuracy as A-Level classifier. As regards B-level classifier, C4.5 exhibited the best performance slightly outperforming JRip and 10NN. More specifically, C4.5 reported 71.21% average classification performance while JRip and 10NN exhibited 70.77% and 69.41%, respectively. Finally, it is worth noticing that based on the previous discussion, we conclude that the best classification performance of the two-level classifier was demonstrated in case 10NN was selected as A-level classifier and C4.5 as a B-level one.

Subsequently, in order to illustrate the efficacy of our two-level classification algorithm, we compared it with the performance of the supervised learning algorithms. Notice that our algorithm uses C4.5 and 10NN, as A-level and B-level classifiers, respectively. Table 6 summarizes the accuracy of each individual classifier which reveals the efficacy of our two-level algorithm. Clearly, the proposed scheme significantly outperforms all individual classifiers, exhibiting higher classification performance.

Table 6. Performance of each individual classifier

Classifier	NB	MLP	SMO	JRip	C4.5	10NN	Two-level (10NN-C4.5)
Accuracy	47.80%	62.10%	64.97%	66.58%	69.73%	68.89%	**78.73**%

5 Conclusions

In this work, we present a two-level machine learning classifier for the accurate prediction of the students' graduation time. The reported experimental results reveal that the proposed algorithm is effective and practical for early student graduation prediction and early identification of students at-risk in order to take proper actions for improving their performance. Our work could provide valuable hints and insights for better educational support by offering customized assistance according to students' predicted performance. It can be used as a reference for decision making in the graduate program admission process.

Our future work directions include the application of the proposed scheme on data from several departments in order to extract useful information about key factors affecting students' performance. Another direction concerns the incorporation of the proposed algorithm in a semi-supervised framework.

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Forecasting Students' Performance Using an Ensemble SSL Algorithm

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Abstract. Educational data mining is a growing academic research area which aims to gain significant insights on student behavior, interactions and performance by applying data mining methods on educational data. During the last decades, a variety of accurate models has been developed to monitor students' future progress, while most of these studies are based on supervised classification methods. In this work, we propose an ensemble semi-supervised algorithm for the prediction of students' performance in the final examinations at the end of academic year. The experimental results demonstrate the efficiency and robustness of the proposed algorithm compared to some classical classification algorithms, in terms of accuracy.

Keywords: Educational data mining · Ensemble learning · Semi-supervised learning · Self-labeled algorithm · Student's performance

1 Introduction

Educational Data Mining (EDM) is an essential process where intelligent methods are applied to extract knowledge hidden in data of students records in order to provide significant insights on student behavior and assist educational decision making support. The importance of EDM is founded on the fact that it allows to extract useful conclusions from sophisticated and complicated questions such as "*find the students who are at-risk in failing the examinations*" or "*find the students who will exhibit excellent performance*" in which traditional database queries cannot be applied [21]. Therefore, EDM is mainly concentrated on the development of accurate models that predict students' characteristics and performance, offering opportunities and great potentials to increase our understanding about the learning processes and students' behavior.

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Secondary education in Greece takes place after six years of primary education and may be followed by higher education. It comprises of two main stages: *Gymnasium* and *Lyceum*. Gymnasium covers the first three years with the purpose to support the development of composite and critical thinking and enrich students' knowledge in all fields of learning. Lyceum covers the following three years aiming in further cultivating the students' personalities while at the same time prepares them for the National examinations in order to proceed to higher education. Essentially, Lyceum acts like a bridge between school education and higher learning specializations that are offered by universities [19–21]. In the end of the 1st grade of Lyceum (A' Lyceum) the students are obligated to select between three possible directions: *Humanity*, *Science* and *Technology* in order to establish the courses which the students will attend in the National examinations. Clearly, this selection constitutes a significant and decisive factor in the life of any student since it defines their future entry in a specific higher academic institution.

Therefore, the ability to predict students' performance in the final examinations of A' Lyceum is considered essential not only for students but also for the educators. More specifically, the "knowledge discovery" can assist students to have a first evaluation of their progress and possibly enhance their performance and teachers to identify slow learners and learning difficulties. Hence, it is of major importance to closely monitor the students' performance in order to identify possible retardation and proactively intervene towards their academic enhancement. Nevertheless, the early identification of students at risk of exhibiting poor performance is a rather difficult and challenging task and even if such identification is possible it is usually too late to prevent students' failure [17,19–22].

Over the last decades, educational institutes have managed to accumulate a large amount of data about their students. Machine learning and data mining techniques constitute a significant prediction tool, offering a first step and a helping hand in analyzing and exploiting the knowledge acquired from students' records. In this context, many researchers in the past have conducted studies on educational data in order to cluster students based on their academic performance. Nevertheless, most of these studies examine the efficiency of supervised classification methods, while ensemble methods [11,19,21] and semi-supervised methods [15,16] have been rarely applied to the educational field. Generally, ensemble methods and semi-supervised methods are two important machine learning techniques. The former attempt to built powerful and accurate predictive models by using multiple learners while the latter attempt to achieve strong generalization by exploiting unlabeled data. Although both methodologies have been efficiently applied to a variety of real-world problems during the last decade, they were almost developed separately. Recently, Zhou [40] presented that ensemble learning algorithms and semi-supervised learning algorithms are indeed beneficial to each other and more efficient classification models can be developed by a combination of diverse classifiers and by leveraging unlabeled data. More analytically, ensemble algorithms could assist semi-supervised algorithms since the combination of classifiers could be more accurate than an individual classifier [7] while semi-supervised algorithms could be useful to ensemble algorithms since unlabeled data can significantly enhance the diversity of a classifier [40,43].

In this work, we propose a new ensemble semi-supervised learning algorithm for predicting the students' performance in the final examinations of "Mathematics" at the end of academic year of A' Lyceum. The specific course has been selected since it has been characterized as the most significant and most difficult course of the Science direction. The proposed ensemble algorithm combines the predictions of three semi-supervised algorithms, based on a voting methodology. The efficiency of the proposed algorithm is evaluated in terms of classification accuracy using several base learners, while our experiments illustrate its efficacy.

The remainder of this paper is organized as follows: Sect. 2 reviews some recent studies of data mining applications in education while Sect. 3 presents a brief discussion of the semi-supervised learning algorithms. Section 4 presents our proposed ensemble semi-supervised learning algorithm and Sect. 5 presents the educational dataset utilized in our study. In Sect. 6, we present a series of tests in order to evaluate the accuracy of proposed algorithm with the most popular classification algorithms. Finally, the last section considers the conclusions and some proposal for future research.

2 Related Work

During the last decade, the application of machine learning and data mining for the development of efficient and accurate prediction models for monitoring students' behavior and future performance has become very popular in modern educational era. Some excellent reviews [3,27,34] have described in detail the most accurate models and developments utilized for gaining significant insights on students' behavior, interactions and progress and summarized the diverse factors which influence students' future performance. A number of rewarding studies have being carried out in recent years and some of them are presented below:

Cortez and Silva [6] conducted a performance study on secondary school students for two core classes (Mathematics and Portuguese). The data were extracted from school records, as well as provided by the students through questionnaires. Four classification algorithms were applied on three data setups, with different combinations of attributes, trying to find out those effecting on the prediction. Based on their numerical experiments, the authors concluded that a good predictive accuracy can be achieved, provided that the first and/or second school period grades are available. Moreover, they stated that students achievements are highly influenced by past evaluations and in some cases there are other relevant features such as social and cultural characteristics of the students which affect students performance.

Ramesh et al. [31] tried to predict the grade of higher secondary students in the examinations and identify the essential predictive variables which affect the performance. Their motivation consists of determine the best classification model and identify the factors influencing the students' performance in final examinations based on a dataset including questionnaire data and students' performance details. Their numerical experiments showed that neural networks exhibited the best classification accuracy. Furthermore, their comparative study revealed that parent's occupation and possibly financial status plays a significant role in students' performance.

Marquez-Vera et al. [23] studied the serious problem of students failure utilizing data from 670 first year high school Mexican students. Firstly, they applied feature selection techniques to detect the factors that most influence student failure and then they rebalanced the data and applied cost sensitive classification in order to resolve the problem of classifying imbalanced data. Additionally, they proposed a genetic programming model to obtain accurate and comprehensible classification rules for predicting the academic status or final student performance at the end of the course. Their experimental results presented that feature selection, cost-sensitive classification and data balancing can also be very useful for improving the classification accuracy.

Recently, Kostopoulos et al. [15] examined the effectiveness of semi-supervised methods for predicting students' performance in distance higher education. Several experiments were conducted using a variety of semi-supervised learning algorithms compared with well-known supervised methods which revealed some interesting results. Based on the previous works, Kostopoulos et al. [16] examined and evaluated the effectiveness of SSL algorithms for the prognosis of high school students' grade in the final examinations at the end of the school year. Their numerical experiments demonstrated the efficiency of semi-supervised methods compared to familiar supervised methods.

Livieris et al. [21] presented a decision support software for predicting high school students' performance, together with a case study concerning the final examinations in course of Mathematics. Their proposed software is based on a hybrid predicting system utilizing a simple voting scheme combining the individual predictions of four individual learning algorithms. Along this line, in [19] the authors introduced an updated version of their software which is based on a novel 2-level classification algorithm. Their numerical experiments reveal that their proposed algorithm identifies the students who are at-risk of failing in the examinations and classifies the students who have successfully passed the course with high accuracy. The motivation and the primary task of their works was to support the academic task of successfully predicting the students' performance in the final examinations of the school year. In more recent works, Livieris et al. [20] applied semi-supervised learning methods to predict the student's future progression and identity their characteristics which induce their performance. Based on their preliminary results, the authors concluded that the application of semi-supervised learning methods on educational data can provide significant insights into students' progress and performance.

3 Semi-supervised Learning

Semi-supervised learning (SSL) constitutes an amalgamation of supervised and unsupervised learning. Compared to traditional classification approaches, SSL utilizes large amount of unlabeled samples together with labeled samples to build an efficient and accurate classifier. Since the acquisition of sufficient labeled samples is cumbersome and expensive and frequently requires the efforts of domain experts, SSL has been established as a powerful and effective machine learning technique. The general assumption of SSL algorithms is to leverage the large amount of unlabeled data in order to reduce data sparsity in the labeled training data and boost the classifier performance, particularly focusing on the setting where the amount of available labeled data is limited. Hence, these methods have the ability of reducing the supervision to a minimum, while still preserving competitive and sometimes better classification performance (see [4,12,16,18,20,41,42] and the references therein).

In the literature, many SSL algorithms have been proposed with different philosophy on exploiting the information hidden in the unlabeled data. Self-training, Co-training and Tri-training constitute the most representative and commonly utilized from this class of algorithms.

Self-training is generally considered as the simplest and one of the most efficient SSL algorithms. This algorithm is a wrapper based SSL approach which constitutes an iterative procedure of self-labeling unlabeled data. According to Ng and Cardie [26] "*self-training is a single-view weakly supervised algorithm*" which is based on its own predictions on unlabeled data to teach itself. Firstly, an arbitrary classifier is initially trained with a small amount of labeled data, constituting its training set which is iteratively augmented using its own most confident predictions of the unlabeled data. More analytically, each unlabeled instance which has achieved a probability over a specific threshold c is considered sufficiently reliable to be added to the labeled training set and subsequently the classifier is retrained. Clearly, the success of Self-training is heavily depended on the newly-labeled data based on its own predictions, hence its weakness is that erroneous initial predictions will probably lead the classifier to generate incorrectly labeled data [43].

Co-training is a SSL algorithm which utilizes two classifiers, each trained on a different view of the labeled training set. The underlying assumptions of the Co-training approach is that feature space can be split into two different conditionally independent views and that each view is able to predict the classes perfectly [9,38]. Under these assumptions, two classifiers are trained separately for each view using the initial labeled set and then iteratively the classifiers augment the training set of the other with the most confident predictions on unlabeled examples. In essence, Co-training is a "*two-view weakly supervised algorithm*" since it uses the self-training approach on each view [26]. The efficacy of Co-training has been extensively studied by Blum and Mitchell [4] and they concluded that if the two views are conditionally independent, then the use of unlabeled data can significantly improve the predictive accuracy of a weak classifier. Nevertheless, the assumption about the existence of sufficient and redundant views is a luxury hardly met in most real world scenarios.

Tri-training [41] consists of an improved version of Co-training which overcomes the requirements for multiple sufficient an redundant feature sets. This algorithm is a bagging ensemble of three classifiers, trained on the data subsets generated through bootstrap sampling from the original labeled training set. In case two of the classifiers agree on a prediction, then they label the unlabeled example with their prediction and augment the third classifier with the newly labeled example. The efficiency of the training process is based on the "*majority teach minority strategy*" which serves as an implicit confidence measurement, avoiding thereby the use of a complicated time consuming approach to explicit measure the predictive confidence.

In contrast to several SSL algorithms, Tri-training does not require different supervised algorithms as base learners which leads to greater applicability in many real world classification problems [12,16,43].

4 An Ensemble SSL Algorithm

We recall that our main goal is to develop a classifier with high classification accuracy by the hybridization of ensemble learning and semi-supervised learning. Generally, the development of an ensemble of classifiers consists of two steps: *selection* and *combination*.

The selection of the appropriate component classifiers is considered essential for the efficacy of the ensemble and the key points for its effectiveness is based on the accuracy and the diversity of the component classifiers [40]. A commonly and widely utilized approach is to generate an ensemble of classifiers by applying diverse learning algorithms (with heterogeneous model representations) to a single dataset (see [24,25,39]). Furthermore, the combination of the individual predictions of learning algorithms takes place through several methodologies (see [7,32,33]) with different philosophy and classification performance.

On this basis, the learning algorithms which constitute the proposed ensemble are: Co-training, Self-training and Tri-training SSL algorithms. These methods are self-labeled methods trying to exploit the hidden information in unlabeled data with complete different way since Co-training is a multi-view method, while Self-training and Tri-training are single-view methods.

Moreover, our proposed ensemble-based classifier combines the individual predictions of the three SSL algorithm via a maximum-probability voting. This combination strategy is considered as the simplest and easiest implementation methodology for combining the individual predictions of component classifiers. Notice that in case the confidence of the prediction of the selected classifier does not meet a predefined threshold, then the prediction is not considered reliable enough. In this case, the output is defined as the combined predictions of three SSL learning algorithms via a simple majority voting, namely the ensemble output is the one made by more than half of them.

An obvious advantages of the utilized combination technique is that it exploits the diversity of the errors of the learned models by utilizing different learning algorithms [24,25] and it does not require training on large quantities of representative recognition results from the individual classifiers.

Subsequently, we present a high-level description of our proposed Ensemble Semi-Supervised Learning (En-SSL) algorithm.

`Algorithm 1`: **En-SSL**

Input: L − Set of labeled training instances.
U − Set of unlabeled training instances.
Parameters: *ThresLev* − Threshold level.

Output: The labels of instances in the testing set.

/* Training phase */
[1]: Train Self-training(L, U) classifier.
[2]: Train Co-training(L, U) classifier.
[3]: Train Tri-training(L, U) classifier.

/* Testing phase */
[1]: for each x from test set
[2]: Apply Self-training, Co-training, Tri-training classifiers on x.
[3]: Find the classifier SSL* with the highest confidence prediction on x.

[4]: if (Confidence of SSL* $\geq$ *ThresLev*)
[5]: SSL* predicts the label y^* of x.
[6]: else
[7]: Use majority vote to predict the label y^* of x.
[8]: end if
[9]: end for

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5 Dataset

The dataset utilized in our study has been provided by the Microsoft showcase high school "*Avgoulea-Linardatou*". For a time period of four years (2012–2015), data of 630 students have been collected concerning the course of "Mathematics".

During the academic year, the educators are required to use a variety of assessment methods including oral examinations, tests, written assignments and exams while the students are obliged to attend the final examinations at the end of the academic year. It is worth noticing that the final exam is marked out of 20 and is of prime importance to the overall final grade.

Table 1 presents eleven (11) time-variant attributes which characterize the performance of each student in each class of the first four years of high school. The selected attributes refer to the students' performance on both academic semesters, utilizing a 20-point grading scale, where 0 is the lowest grade and 20 is the perfect score. The assessment of students during the academic year consists of oral examination, two 15-min pre-warned tests, an 1-h exam, the overall semester performance of each student in the 1st and 2nd semester and his/her performance at the final examinations.

The oral grade is defined by several written assignments and frequent oral questions, evaluating students' understanding of basic mathematical terms and concepts daily. The 15-min tests include multiple choice questions and short answer problems. The 1-h exams cover a wide range of the curricula and include several theoretical and multiple choice questions, as well as a variety of problems requiring arithmetic skills and critical analysis. The overall semester performance of each student addresses the personal engagement of the student in the course and his progress. Finally, the last attribute concerns the students' performance in the final examinations (2-h exam). Many related studies have shown that such attributes assess students' understanding of important mathematical concepts and topics daily and have a significant impact in students' success in the examinations [6,21,22,30].

Table 1. Attributes description for each class

Attribute	Type	Values
Oral grade of the 1st semester	Integer	$[0, 20]$
Grade of the 1st test of the 1st semester	Real	$[0, 20]$
Grade of the 2nd test of the 1st semester	Real	$[0, 20]$
Grade of the final examination of the 1st semester	Real	$[0, 20]$
Grade of the 1st semester	Integer	$[0, 20]$
Oral grade of the 2nd semester	Integer	$[0, 20]$
Grade of the 1st test of the 2nd semester	Real	$[0, 20]$
Grade of the 2nd test of the 2nd semester	Real	$[0, 20]$
Grade of the final examination of the 2nd semester	Real	$[0, 20]$
Grade of the 2nd semester	Integer	$[0, 20]$
Grade in the final examinations	Real	$[0, 20]$

Furthermore, since the early prediction of the students' performance at the final examination of A' Lyceum is of great importance, similar to [19–22] we have created two datasets based on the attributes presented in Table 1.

- DATA_{G}: It contains the attributes which concern the students' performance in A', B' and C' Gymnasium (33 attributes + class).
- DATA_{GL}: It contains the attributes which concern the students' performance in A', B' and C' Gymnasium and A' Lyceum (43 attributes + class).

Finally, the students' were classified based on the performance in the final examinations of A' Lyceum (2-h exam) utilizing the following four-level classification: 0–9 (poor), 10–14 (good), 15–17 (very good), 18–20 (excellent) as in [19–22]. This classification scheme also used in students' performance evaluation in the Greek schools.

6 Experimental Results

In this section, the classification performance of the proposed algorithm was compared to its component SSL algorithms and in particular Self-training, Co-training and Tri-training in terms of classification accuracy. Accuracy is one of the most frequently used measures for assessing the overall effectiveness of a classification algorithm [37] and it is defined as the percentage of correctly classified instances. Furthermore, the most popular and commonly used supervised algorithms were deployed as base learners: Naive Bayes (NB) [8], Multilayer Perceptron (MLP) [36], Sequential Minimum Optimization (SMO) [28], C4.5 decision tree algorithm [29], JRip [5] as a typical rule-learning algorithm and 3-NN [1].

The classification accuracy of all learning algorithms was evaluated utilizing the standard procedure called stratified 10-fold cross-validation i.e. the data was separated into folds so that each fold had the same distribution of grades as the entire data set. Moreover, the implementation code was written in JAVA, using the WEKA Machine Learning Toolkit [13]. The configuration parameters for all SSL algorithms used in our experiments are presented in Table 2. Regarding the base learners, the default parameter settings included in the WEKA software were utilized in order to minimize the effect of any expert bias by not attempting to tune any of the algorithms to the specific datasets. In order to study the influence of the amount of labeled data, three different ratios of the training data were used: 10%, 20% and 30%.

Table 2. Parameter specification for all the SSL methods employed in our experiments

Algorithm	Parameters
Self-training	MaxIter = 40
	$c = 95\%$
Co-training	MaxIter = 40
	Initial unlabeled pool = 75
Tri-training	No parameters specified
En-SSL	$ThresLev = 95\%$

Tables 3, 4, 5, 6, 7 and 8 present the classification performance of each SSL algorithm regarding all base learners and the best accuracy among the different algorithms in each experiment is highlighted in bold style. Additionally, a more representative visualization of the average classification performance of the compared SSL algorithms is presented in Figs. 1 and 2. Despite the ratio of labeled instances, En-SSL algorithm presents by far the best classification results, outperforming all SSL algorithms, relative to both datasets. It is worth noticing that our proposed algorithm exhibits the best classification accuracy utilizing JRip and C4.5 as base learners. Furthermore, the interpretation of Figs. 1 and 2 reveal that En-SSL illustrates the best average classification accuracy, significantly outperforming all SSL algorithms, regarding both datasets.

Table 3. Comparison of SSL algorithms using NB as base learner

Dataset	Ratio	Tri-training (NB)	Co-training (NB)	Self-training (NB)	En-SSL (NB)
DATA_G	10%	69.80%	69.40%	**70.57%**	**70.57%**
	20%	**70.56%**	69.42%	70.20%	70.19%
	30%	**70.93%**	70.19%	70.19%	70.56%
DATA_{GL}	10%	77.01%	**77.60%**	77.01%	77.01%
	20%	**77.76%**	77.10%	77.01%	**77.76%**
	30%	77.39%	77.10%	**77.41%**	77.02%

Table 4. Comparison of SSL algorithms using MLP as base learner

Dataset	Ratio	Tri-training (MLP)	Co-training (MLP)	Self-training (MLP)	En-SSL (MLP)
DATA_G	10%	76.45%	78.15%	77.79%	**78.56%**
	20%	74.40%	74.44%	76.30%	**77.45%**
	30%	72.89%	73.28%	75.53%	**77.05%**
DATA_{GL}	10%	77.76%	68.72%	**78.92%**	78.56%
	20%	78.96%	77.41%	77.81%	**80.84%**
	30%	75.87%	75.98%	**78.93%**	**78.93%**

Table 5. Comparison of SSL algorithms using SMO as base learner

Dataset	Ratio	Tri-training (SMO)	Co-training (SMO)	Self-training (SMO)	En-SSL (SMO)
DATA_G	10%	71.27%	**73.16%**	64.57%	69.42%
	20%	71.30%	68.35%	69.83%	**71.35%**
	30%	**72.81%**	68.35%	70.20%	71.32%
DATA_{GL}	10%	79.59%	80.03%	75.81%	**80.73%**
	20%	77.36%	75.50%	72.75%	**78.11%**
	30%	79.56%	78.50%	73.90%	**80.70%**

Table 6. Comparison of SSL algorithms using C4.5 as base learner

Dataset	Ratio	Tri-training (C4.5)	Co-training (C4.5)	Self-training (C4.5)	En-SSL (C4.5)
$DATA_G$	10%	78.13%	78.16%	77.41%	**78.89%**
	20%	78.53%	77.76%	**79.29%**	77.78%
	30%	**77.36%**	73.28%	**77.36%**	75.85%
$DATA_{GL}$	10%	81.20%	81.14%	77.02%	**81.44%**
	20%	79.29%	80.01%	79.30%	**80.04%**
	30%	81.20%	77.46%	81.89%	**83.05%**

Table 7. Comparison of SSL algorithms using JRip as base learner

Dataset	Ratio	Tri-training (JRip)	Co-training (JRip)	Self-training (JRip)	En-SSL (JRip)
$DATA_G$	10%	78.46%	78.82%	80.34%	**82.64%**
	20%	77.39%	78.11%	75.87%	**80.77%**
	30%	77.36%	79.67%	77.35%	**79.99%**
$DATA_{GL}$	10%	77.72%	79.96%	78.92%	**81.51%**
	20%	78.95%	78.49%	79.66%	**81.92%**
	30%	81.10%	80.33%	80.37%	**81.88%**

Table 8. Comparison of SSL algorithms using 3NN as base learner

Dataset	Ratio	Tri-training (3NN)	Co-training (3NN)	Self-training (3NN)	En-SSL (3NN)
$DATA_G$	10%	68.38%	70.24%	69.05%	**71.35%**
	20%	70.60%	69.47%	71.77%	**72.11%**
	30%	**72.05%**	67.65%	67.62%	71.74%
$DATA_G$	10%	73.58%	72.11%	**75.46%**	74.73%
	20%	75.87%	72.81%	75.87%	**76.24%**
	30%	**77.35%**	74.36%	69.4 %	75.09%

Table 9 presents the number of wins of each one of the tested algorithms according to the utilized ratio in the training set, while the best scores are highlighted in bold. Notice that draw cases between algorithms have not been encountered. The above aggregated results show that En-SSL is by far the most effective algorithm, reporting the highest accuracy in 7, 9 and 5 cases, using a labeled ratio of 10%, 20% and 30%, respectively.

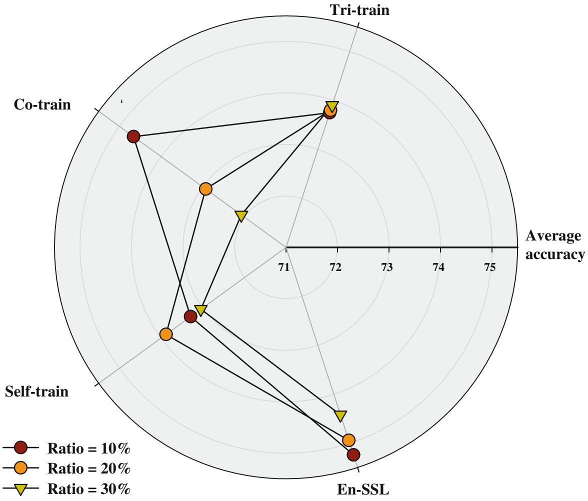

Fig. 1. Average classification accuracy of all SSL algorithms for $DATA_G$

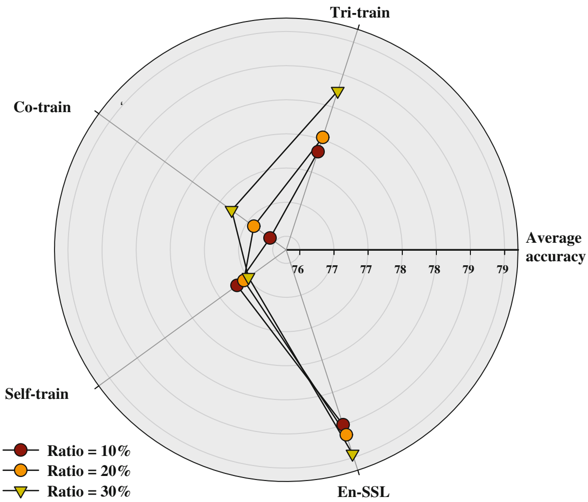

Fig. 2. Average classification accuracy of all SSL algorithms for $DATA_{GL}$

Table 9. Total wins of each SSL algorithm

Ratio	Tri-training	Co-training	Self-training	En-SSL
10%	0	2	2	**7**
20%	1	0	1	**9**
30%	4	0	1	**5**

In machine learning, the statistical comparison of multiple algorithms over multiple data sets is fundamental and it is usually carried out by means of a statistical test [16]. Therefore, in order to evaluate the rejection of the hypothesis that all the algorithms perform equally well for a given level and highlight the existence of significant differences between our proposed algorithm and the classical SSL algorithms, we utilized the non-parametric Friedman Aligned Ranking (FAR) [14] test. Notice that, since the test is non-parametric, it does not require commensurability of the measures across different data sets, it does not assume normality of the sample means and it is robust to outliers. Moreover, the Finner post hoc test [10] with a significance level $\alpha = 0.05$ was applied a post hoc procedure to detect the specific differences among the algorithms.

Tables 10, 11 and 12 present the information of the statistical analysis performed by nonparametric multiple comparison procedures over 10%, 20% and 30% of labeled data, respectively. The best (lowest) ranking obtained in each FAR test determines the control algorithm for the post hoc test. Clearly, the proposed algorithm exhibits the best overall performance, illustrating the highest probability-based ranking, presenting statistically better results, relative to all labeled ratio.

Table 10. FAR test and Finner post hoc test (labeled ratio 10%)

Algorithm	Friedman Ranking	Finner p-value	post-hoc test Null Hypothesis
En-SSL	14.0833	–	–
Co-training	25.9167	0.038415	Rejected
Tri-training	27.9167	0.023169	Rejected
Self-training	30.0833	0.015280	Rejected

Table 11. FAR test and Finner post hoc test (labeled ratio 20%)

Algorithm	Friedman Ranking	Finner p-value	post-hoc test Null hypothesis
En-SSL	11.1250	–	–
Tri-training	23.4167	0.031508	Rejected
Self-training	26.9583	0.008390	Rejected
Co-training	36.5000	0.000027	Rejected

Table 12. FAR test and Finner post hoc test (labeled ratio 30%)

Algorithm	Friedman Ranking	Finner p-value	post-hoc test Null hypothesis
En-SSL	14.3750	–	–
Tri-training	20.4583	0.287165	Accepted
Self-training	29.2917	0.013556	Rejected
Co-training	33.8750	0.001935	Rejected

7 Conclusion and Future Research

In this work, we propose a new SSL algorithm for predicting the students' performance in the final examinations at the end of the 1st class of Lyceum. Our experimental results illustrated that our proposed classification algorithm is proved to be effective and practical for the early and accurate prediction of students' progress, as compared to some traditional SSL algorithms.

In conclusion, we point out that the students' attributes utilized in our work do not constitute a conclusive list. An extension can introduce new attributes and other criteria which were not in the current database, but are collectable by tutors and may potentially influence the performance and the quality of the prediction of student's performance i.e. students' characteristics (social and cultural), more tests, more written assignments. Nevertheless, the identification of which attributes should be utilized or which have higher impact on the students' performance is still under consideration by many researchers [2,34,35].

Furthermore, since our experimental results are quite encouraging, another direction for future research would be to enlarge our experiments with more schools (private and state) and school years and evaluate the proposed algorithm for predicting the students' performance at national level examinations for admission to higher education institutes.

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Engaging Postgraduate Students in a Wiki-Based Multi-cycle Peer Assessment Activity

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Abstract. The use of peer assessment to assist student learning has been widely employed in educational settings. Wiki has been used as an environment to hold peer assessment activities because of its interactive nature of supporting collaboration among multiple users. This paper presents a multi-cycle peer-assessment activity where postgraduate students explore various Web 2.0 tools to develop learning objects and use a wiki for presenting their work, performing the evaluations, evaluating their assessors and presenting their revisions. The study concludes that the context of the peer-assessment activity served the roles of author and assessor adequately, the students valued the use of the wiki, and wikis are an effective tool for conducting peer-assessment activities and fostering interaction.

Keywords: Peer-assessment · Wiki · Higher education · Learning objects

1 Introduction

Assessment is central to the practice of education and many researchers assert that there is an intimate association between instruction, learning, and assessment [1]. Berry [2] points out that assessment for learning should be used to promote, induce, and reinforce learning. Contemporary assessment methods attempt to change place and function of the assessor and involve students actively in the assessment process. Peer-assessment aims to lead towards a student-centered learning environment, where assessment is represented as a tool for learning, and achieves goals, which are difficult to attain with traditional assessment methods [3]. Peer-assessment enables students to actively participate in the assessment process, develop important cognitive skills such as critical thinking, evaluative abilities and regulation, see how others tackle/solve problems, get inspiration from their peers' work, learn to criticize constructively and suggest improvements, accept peer criticism, reflect on the amount of effort they put into their work, and judge the appropriateness of the standards they set for themselves [3–5]. Well-constructed self-assessment and peer-assessment exercises have the potential to provide valuable learning experiences and encourage lifelong learning [6].

Advances in computer and network technology enable the development of educational settings that implement effectively peer-assessment by eliminating communication restrictions, enabling the provision of immediate feedback and allowing

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instructors to monitor students' progress at any time during the assessment process. Towards this direction, a number of web-based educational environments have been developed such as NetPeas [6], SPARK [7], WebCoM [8], SWoRD [9], Web-SPA [5], PASS [10], Waypoint [11], PECASSE [12]. Most of these environments were mainly developed by universities aiming to fulfill specific objectives and needs and are not public available. As Web 2.0 emerging technologies are gaining attention in teaching and learning, the exploitation of wiki seems to be a promising tool for peer-assessment activities.

Recent publications suggest the use of wikis to support teaching, promote learning, collaboration and student interaction and facilitate social constructivist learning processes [13–18]. The most powerful aspect of wikis is their collaborative nature. Wikis, as equipped with the appropriate tools, provide users with asynchronous access, version control, change tracking, and comment capacities all of which are beneficial for authoring activities. Easily accessible and functional, a wiki can be seen as a viable tool to extend collaboration beyond the confines of the classroom. Students use wikis for a great diversity of learning activities, such as "to publish homework assignments, maintain portfolios, peer review writing, post artwork, download music for rehearsals, and review drills for physical education" ([11] p. 10). Much of the research has shown that students tend to have a positive view of collaboration activities with wikis.

Wikis have great potential for facilitating peer assessment as each contribution of every student in a wiki is published online [20]. Few studies report on how wiki can support the peer-assessment process [18, 20, 21, 25]. Skeele [11] suggests that educators should continue to explore the blending of peer evaluation and new technologies to enhance teaching and promote learning.

Towards this research direction and for exploratory purposes, a case-study approach was selected to be followed aiming to investigate the effectiveness of using wiki as a peer-assessment tool. In particular, the exploratory case study conducted designates the use of wiki in supporting multi-cycle peer-assessment activities and explores students' perceptions of the peer-assessment online process and the use of wiki as peer-assessment tool. The following sections describe in details the research setting, the research questions and the results revealed. Finally, conclusions are drawn and future research directions are outlined.

2 Research Methodology

2.1 Participants, Procedure and Tasks

Thirty three (33) postgraduate students participated in the study in the framework of the "Design of Educational Software" course offered by the Department of Informatics and Telecommunications of the University of Athens. Twenty seven (27) had graduated from an Informatics Department and six (6) of them from other departments (i.e. Mathematics, Biology, Physics, and Primary Education). Also, six (6) of the 27 participants were informatics teachers while the rest were working as software engineers. The course is lecture based and was supported by the responsible professor and the three course assistants.

In the context of the course, the students were involved in a multi-cycle peer-assessment activity. The objective of the activity was twofold: (i) to engage students in the role of educational software developer through the development of learning objects, and (ii) to cultivate skills in evaluating learning objects. In the context of the study, the learning object is considered as "any digital resource that can be reused to support learning" [27]. In this sense, a learning object may be a digital image, a live or pre-recorded video, small bits of text, animations, web-delivered applications, like Java applications or entire web pages that combine text, images and other media.

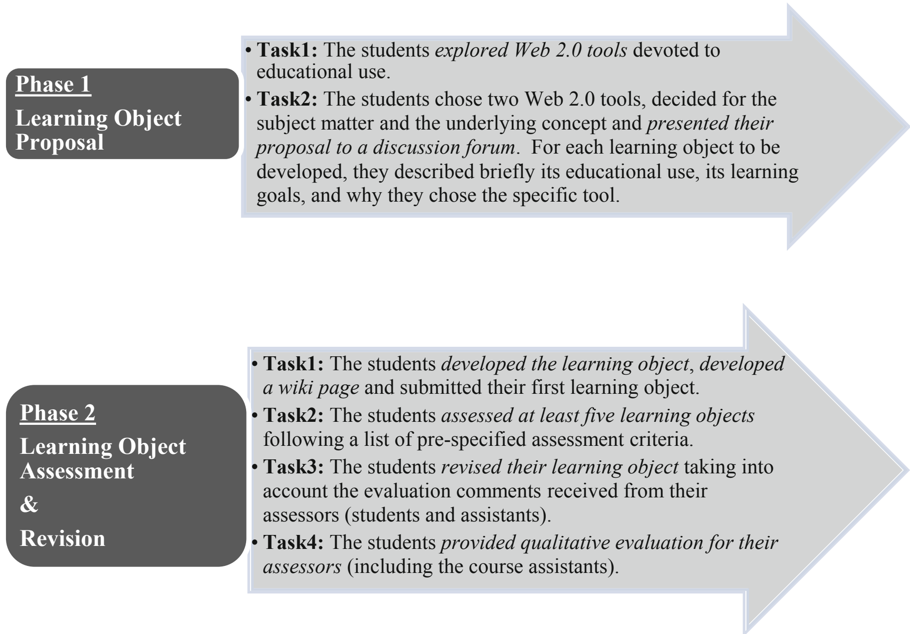

Fig. 1. The phases and the tasks of the multi-cycle peer-assessment activity.

The whole peer-assessment activity was carried out through a wiki administered by the course assistants consisting of the phases and tasks depicted in Fig. 1.

As depicted in Fig. 2, each student's page was consisted of: (i) a link to the learning object, (ii) the description of the learning object, followed by the assessment criteria. For each criterion a discussion forum was supported to enable students to exchange their opinions and pose questions (Fig. 3).

Although, the active involvement of learners in designing the assessment scheme (e.g. assessment criteria) is seen as beneficial in helping them understand how they will be assessed [22] and how they will conduct the evaluation, sometimes, mainly due to their inexperience in defining meaningful and common understanding assessment criteria, learners appear unenthusiastic to participate actively in the design phase of the assessment scheme [23]. Therefore, in Phase 2, Task 2, the responsible and the course assistants provided a list of assessment criteria. In particular, students were asked to provide feedback comments to their peers on 8 criteria: (1) attainment of the learning objectives, (2) educational level suitability, (3) educational content, (4) Web 2.0 tool suitability, (5) pedagogical use of the object, (6) Web 2.0 tool description, (7) proposals for alternative tools used, and (8) ideas for enriching/improving the learning object.

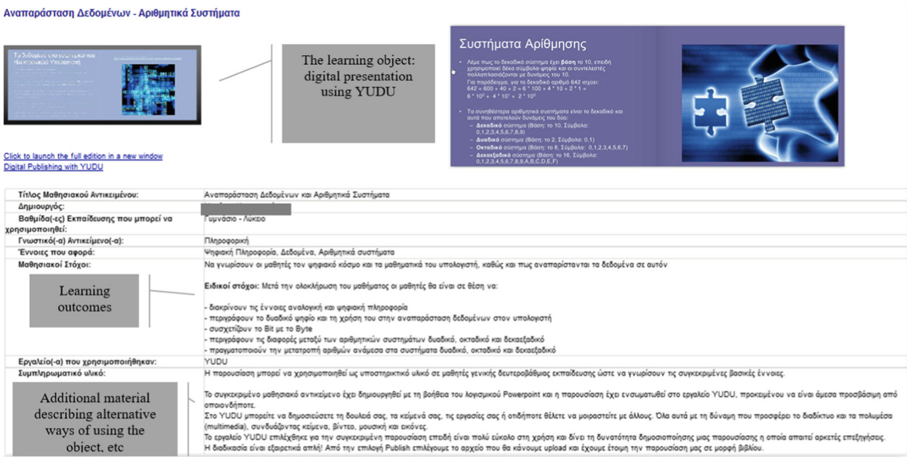

Fig. 2. The wiki page created by a student for the first learning object concerning the binary system.

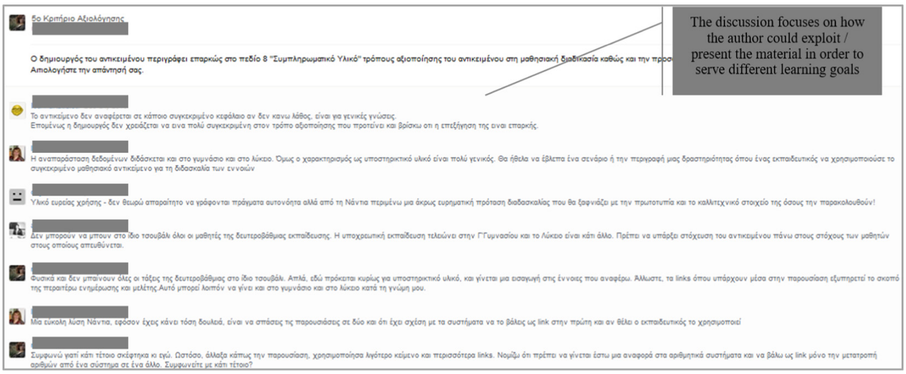

Fig. 3. The discussion for the 5th criterion "pedagogical use of the object" for the learning object depicted in Fig. 2.

The assessment process and the interaction between the author (the student who developed the learning object and the corresponding wiki page) and the assessors (peers and course assistants) were facilitated by the "Discussion forum" section associated to each wiki page. In this section, the authors were responsible to open a post for each assessment criterion, through which short dialogues concerning the specific criterion could take place among the student-author and the assessors. The students could follow up and provide responses to the feedback they received and/or seek clarifications when the feedback was not clear and understandable. Figure 3, presents the discussion for the 5th criterion “pedagogical use of the object, where we can see the exchange of messages between 4 assessors and the author of the learning object. As assessors, the students had to evaluate at least five learning objects in total (Phase 2 and Phase 3). They used the asynchronous discussion forum in order to post their feedback comments as assessors and to pose questions as authors.

At the end of each phase, the course assistants were summarizing the results and provided feedback in terms of the learning objects developed and the corresponding wiki pages as well as of the students' performance acting as assessors.

2.2 Objectives and Data

To attain the research objective, the following research questions were posed:

RQ1: Is wiki considered a suitable tool to support multi-cycle peer-assessment activities?
RQ2: Which is students' opinion about the peer-assessment activity, the wiki and the whole process followed?
RQ3: How students interacted/participated in the wiki?

Data were collected from multiple sources: (i) the contents of the wiki pages that each student created, (ii) the log files gathered by the wiki site (e.g. History tool), (iii) the students' peer-evaluation results from the Discussion fora, (iv) the students' answers to a questionnaire, and (v) the results reported from the course assistants. Upon the end of the process, the students were asked to complete and submit a questionnaire involving three axes of questions: the peer-assessment process in general and in terms of various characteristics and the use of the wiki environment in the context of the course. Thirty one (31) out of the 33 participants submitted the questionnaire.

2.3 Results

Research Question 1: Is Wiki Considered a Suitable Tool to Support Multi-cycle Peer-Assessment Activities? The analysis of the wiki pages showed that the students developed sixty eight (68) learning objects using thirty seven (37) different Web 2.0 tools. In some cases, they used more than one tool to integrate their object (e.g. a tool for presentation and a tool for creating quiz). The objects developed cover both the primary and secondary education, and various subject matters. Due to students' background, a significant number of objects addressed the Informatics subject matter and the secondary education. In total, 273 evaluations were encountered (the assistants' evaluations are not included). The average number of objects that students evaluated was 8; six students evaluated the minimum required number of objects (that is 5 objects) while there was a student that evaluated 16 objects. As the students were free to choose the objects they wanted to evaluate according to their interests and their background, some learning objects were evaluated only from the assistants or from one student while others had eight to ten different evaluations. The average grade given by the course assistants for the first object was 7.5 while for the second reaches 8.5. Some students invested a lot of effort to the use of the Web 2.0 tool (e.g. tools for simulation), others explored easy tools (e.g. tools for subtitling) while others focused mostly on the educational content (e.g. development of a wiki). The students had difficulties in defining learning objectives and proposing alternative ways for using the object in the educational practice; as mentioned above, the majority of them had no relation with the education field.

Following students' evaluations, the assistants evaluated the assessors' work. The average score of the evaluation for the first object was 6.52, in the range of 5 to 9. Some evaluations were actually very good, with accurate observations, suggestions and comments. Almost half of the evaluations were characterized as moderate or indifferent. On the contrary, the evaluations for the second object were more focused highlighting the strengths and the weaknesses of the objects. The average score was 8.6 with a range from 7 to 10.

The messages exchanged during the evaluation phases surpass 4000 while the average number of messages per criterion is about 6.

At the end of each evaluation phase, the students revised their learning objects and the corresponding material, and evaluated their assessors. They commented on the assessors' comments and feedback, elaborated on the revisions they made or on those comments that they didn't took into consideration and gave a qualitative characterization of their assessor's work. The majority of the students considered as positive their assessors' comments. They stated that their peers tried to give useful hints and guidance in the direction of improving their learning objects.

It has to be mentioned, that the use of tags for the organization of the developed learning objects (tags for the education level, subject-matter, and kind of Web 2.0 tool used) facilitated students to easily locate the learning objects and select the ones suited better to their interests for evaluation.

In summary, the students had no difficulties in using the wiki environment either during the presentation of their learning object or during the evaluation. They participated in the discussion fora that they set for each assessment criterion and had positive attitude in elaborating on their comments.

Research Question 2: Which is Students' Opinion About the Peer-Assessment Activity, the Wiki and the Whole Process Followed? As depicted in Table 1, the students were very positive for the whole process followed. They stated that the activity context is closely related to the course learning outcomes (Question No. 1), they had the chance to apply characteristics from the educational software (lectures material) and actively participate in various phases of the software development life cycle (development/evaluation/revision) and apply design principles for educational software (Question No. 7 and 8). A number of students stated "I felt as a member of a working team having as an objective to develop educationally valuable objects and act with responsibility as assessor". The students had a high degree of interaction and believe that the context of the peer-assessment activity stimulated their communication, especially in the framework of the 2nd Task of Phases 2 and 3 (Question No. 2).

However, the majority of students stress that the whole process was very demanding and time consuming (Questions No. 3 and 4). In addition to the revisions they made taking into consideration their peers' comments, some of them made additional changes as a result to the experience they gained from the process followed (Question No. 5 and comments presented in their wiki pages). Most of the students were satisfied with the context of the peer-assessment activity and the whole process and expressed their willingness to be involved in similar activities in the future (Question No. 6). The positive attitude of the students toward peer-assessment is consistent with other studies results on students' satisfaction with peer-assessment [18] as the visibility and user friendliness of wiki can foster student-centered learning and peer assessment.

A considerable number of students prefer to use their names both in the phase of submitting their work as well as in the phase of evaluating others' work (Questions No. 9 and 10). This is not in keeping with previous findings and suggestions [24, 25] and further investigation is needed. Xiao and Lucking [20] recommend to have all students use a login name in the peer assessment (not use of real names) to ensure the anonymity of the process by using wikis.

Regarding the evaluation process, students felt uncomfortable as they had to play a role that they were not used to; they had minor or very little experience with teaching and evaluation. Therefore, a considerable number (18 students) considered useful to be educated before acting as assessors (Question No. 11). It has to be mentioned that some students mentioned that the education phase is not necessary as the activity was very clearly defined and the assessment criteria were defined by the course assistants. This comment is in line with the results of Question No. 13, where most of the students feel more comfortable when they have to apply already defined assessment criteria than to have to define their own and also confirms authors' initiative to provide a list of assessment criteria. However, half of them would like to change the assessment criteria (Question No. 14) by adding new ones or substituting some of them with others. In all cases, students expressed their confidence to the provided list of assessment criteria and commented that it helped them to be objective in their feedback (Question No. 12). They trusted their assessors and characterized as correct the evaluations they received (Question No. 16). Furthermore, only few of the students (7) were willing to provide a grade (Question No. 15) as they consider more targeted and helpful the qualitative assessement.

Most of the students consider useful the evaluation of the assessors' phase (Question No. 17) and revisited the pages of the objects they assessed (Question No. 18), in order to read the evaluation their peers made and ascertain whether their comments were realized in the revised objects. A considerable number of students believe that they tried to be right and unbiased in their evaluations and they provided productive comments (Questions No. 19 and 20). They consider very useful the provision of qualitative comments and they trusted their assessors (Questions No. 21 and 22). It has to be noted that all students took into account their peers' feedback (Question No. 23). This complies with the qualitative evaluation they made to their assessors. As mentioned in the Research Question 1 section, the students characterized as very good and very positive the feedback they received. Most of them proceeded to comparisons between the objects they were assessing and the objects they developed (Question No. 24). As mentioned above, this attitude seems to have affected the revisions they made to their own objects trying to improve their learning object as much as they could.

From the students' answers to questions 26, 27, 28 and 29, it seems that the wiki environment effectively supported the process and the discussion fora facilitated their communication and the exchange of evaluation comments.

Table 1. Students' answers to the questionnaire

No.	Question	Evaluation range (−2: not at all … 2: a lot)				
		−2	−1	0	1	2
Peer-Assessment - General						
1.	Do you believe that the process followed promotes the learning outcomes?		2	3	5	21
2	Do you believe that the process followed increases learners' interaction?			1	9	21
3.	Do you consider the process followed as demanding?		4	8	14	5
4.	Do you consider the process followed as time consuming?		2	9	8	12
5.	Did the peer-assessment process help you in improving your own learning objects?			3	14	14
6.	Would you like to get involved in peer-assessment processes in the future?	5	1	8	9	8
7.	During the peer-assessment phases (development, evaluation, revision), did you apply any design principles for educational software?		3	4	12	12
8.	Do you believe that the whole process involved you actively in acting as educational software developer?	1	1	3	10	16
Peer-Assessment - Anonymity						
9.	Would you prefer your work to be submitted for evaluation anonymously?	16	2	7	1	5
10.	Would you prefer to act as an anonymous assessor?	14	4	5	3	5
Peer-Assessment - Evaluation process						
11.	Do you believe that it would be useful to be educated before acting as an assessor?	1	7	5	9	9
12.	Do you believe that the use of assessment criteria helped you to be objective in your evaluation?			2	10	19
13.	The assessment criteria were set by the responsible of the course. Would you prefer to set your own criteria?	13	6	7	3	2
14.	Would you like to change the assessment criteria?	6	8	2	9	6
15.	Would you like to assign a grade to the work you evaluated?	12	4	8	3	4
16.	Do you believe that the evaluations you received were correct?	1	1	2	19	8
Peer-Assessment - Assessors' Evaluation						
17.	Do you consider useful the possibility to evaluate your assessors?	1	2	7	6	15

(*continued*)

Table 1. (*continued*)

No.	Question	Evaluation range (−2: not at all … 2: a lot)				
		−2	−1	0	1	2
18.	Did you revisit the works you evaluated, in order to read the evaluation your co-learners made for you?	1	1	7	7	15
Peer-Assessment - Feedback						
19.	Do you feel confident for your comments?			5	10	16
20.	Do you believe that your evaluation/feedback was complete?		3	4	14	10
21.	Do you consider the feedback you received as useful?	1		4	7	19
22.	Do you trust the feedback you received?			4	17	10
Peer-Assessment - Revision Process						
23.	During the revision phase, did you take into account the feedback you received?			2	10	19
24.	Did you make any comparisons of your learning object with your peers' object?	6	3		12	10
25.	Did you take into account your peers' work in the revision phase?	2	4	12	11	2
Wiki as a peer-assessment tool						
26.	Do you believe that the wiki environment satisfies the goals of the process?			1	8	22
27.	Do you believe that the use of the wiki environment provides flexibility?		1	1	9	20
28.	Do you believe that the use of asynchronous discussion facilitated the evaluation?	1		3	10	17
29.	Do you consider useful the possibility to collaborate – interact through asynchronous discussion fora?			5	11	15

Research Question 3: How Students Interacted/Participated in the Wiki? The analysis of students' interaction in the wiki was based on a number of descriptive indicators.

As far as the degree of discussion concerning the open answer criteria 5, 6, 7 and 8, a random sample of eighteen (18) in total learning objects was analyzed (Table 2). It seems that students discussed a lot on the exploitation of the learning object in the educational practice (criterion 5) and on ideas for enriching/improving the learning object (criterion 8). The students focused on the pedagogical use of the learning objects rather than on technical issues (e.g. use of alternative Web 2.0 tools).

Table 2. Number of students participated, more than once, in the discussion of criteria 5, 6, 7 and 8

After submitting …	Criteria			
	5	6	7	8
1st learning object	9	4	3	8
2nd learning object	5	3	1	11

Regarding students' revision on the objects' pages and the discussion pages, Table 3 shows that students were more active during the second and the third month of the activity. This is in line with the schedule of the activity, as they had to create the wiki page for their first object during the second month and they had to assess some of their peers' learning objects as well. While during the third month, they had to improve their first object, publish their second object and assess some of their peers' learning objects.

Table 3. Number of revisions and messages per month

Month	Page revisions	Messages
1st	3	15
2nd	480	900
3rd	796	2047
4th	237	33

In the initial phase of determining the learning objects (subject matter, concepts, Web 2.0 tools), a total of 32 discussions were created. The students restricted themselves only to the discussions they initiated. A small number of messages (50) were sent as comments from the 33 participants to their peers' proposals while the three assistants sent 164 messages in order to approve/comment/clarify students' ideas.

3 Conclusion

In line with other exploratory studies, this paper provides some evidence that wiki can effectively support educational settings [26]. Wiki provides all the necessary facilities for asynchronous discussion, revision and history of pages. Assessment activities that use wiki promote students' active involvement and self-confidence [28]. In this context, wiki can be used in the implementation of peer assessment activities both in the authoring and assessment phases.

The study showed that the wiki as a tool supported effectively the completion of the activity. The provided discussion fora enabled students' interaction between them and with the course assistants. The "Help Page" facilitated the provision of guidance at any time by all participants. The course assistants believe that such an activity requires careful design and support. As it was quite demanding and involved two cycles, the assistants had to track the fora and the messages quite often at a daily basis and respond to the students' questions.

The students had the possibility to explore various tools and experiment with objects addressing similar concepts but developed with different tools. As the students under consideration were technically adept, they had minor problems in the use of the wiki environment or the Web 2.0 tools but needed support at the pedagogical level. In certain cases, the course assistants' feedback focused on alternative uses of the developed object and provided hints on improvements to be made in order the objects to suit better in the real educational practice (e.g. in a case of a learning object concerning a presentation, the feedback advised the student to make slower the presentation flow and use the presentation in a more exploratory practice).

The findings of the case-study show that students valued/seized the opportunity to use a wiki. Most students enjoyed the experience, they felt that the peer-assessment activity was well suited to the course and was realized as a meaningful and authentic learning task. Their engagement in a multi-cycle peer-assessment activity, improved their capabilities in developing learning objects and in assessing their peers' work. Students evaluated leaning objects of their peers in two stages. In the first stage, they evaluated the first object and received direct and indirect feedback from the assistants and from their peers. The feedback made them reflect on their thoughts and get involved in a self-reflective learning process. During the second stage they transfered their improved assessment skills in developing and evaluating the second learning object resulting in increase of the average grade. The supported facilities (discussion fora, use of tags) can foster student-to-student and student-to-teacher interaction as well as the presentation and structuring of the material. Overall, the results of the study lead to the implication that wikis can support instructors to manage web-based peer assessment activities.

The questionnaire used for the investigation of students opinion, seems that misses open-ended questions that could give students the opportunity to clarify their opinion. For example, they could elaborate on why some students prefer to conduct a peer-assessment activity anonymously or on their intention to have the opportunity to change/enrich the assessment criteria. There are main directions for future research: first, a training session could be introduced to instruct participants how to perform an assessment prior to the actual assessment, second give them the possibility to explore learning material before developing their own and third promote a more active involvement to the assessor role (e.g. defining the assessment criteria).

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Assessing the Usage of Ubiquitous Learning

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Abstract. High success is the main objective of any education system. Thus, in any educational organization, the education offered must be efficient and effective. It is evident that some factors are critical for such achievements. Ubiquitous learning systems and interactive video courses incorporate features which can be measured using learning analytics. In this paper, we adopt nine dimensions of u-learning. According to the learners' interactions, we suggest indexes and metrics for the assessment of ubiquitous and interactive video courses. These indexes and metrics are associated with the presented u-learning dimensions. The proposed metrics are calculated for a case study in a higher education institute, and the results are explained and associated with the introduced u-learning dimensions.

Keywords: Ubiquitous learning · Indexes and metrics · Learning analytics

1 Introduction

The rapid growth of mobile computing devices assisted to their usage, increasingly, in fields such as e-commerce and e-learning [1]. Nowadays, most adults and adolescents own and use mobile computing devices not only for fun but for professional and educational purposes as well [3]. The modern Internet user is experienced, fastidious to offered services, considerate and capable of being self-addressed [4]. Consequently, web applications should also be adapted to his/her profile.

The main distinguished learning methods that exist and are assimilated from educational institutions worldwide are the following:

Traditional Learning: This is the well-known process of an educator that instructs in a classroom or audience performing with a physical presentation based on slides and/or blackboard, and distribution of hardcopy notes or library book references.

Electronically Assisted Learning: This is the learning process where most of the transferred knowledge is handled out digitally. The use of an LMS system (Learning Management System) and its modules facilitate knowledge discovery and learner's

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evaluation, and provide course exercises, uploaded slide material for off-line view, forum, wiki, homework-tasks upload and course final examination capabilities [5]. These amenities restrict traditional learning to minimum physical interaction, mostly for the purpose of oral examinations. LMS usage methodology presentation and analysis of complicated course material questions are presented by Hwang et al. [6]. Electronically assisted learning can be characterized as highly, medium or low blended with the traditional learning methods, depending on the usage of the LMS course modules by the instructor.

Video Conference Learning: This learning process eliminates the need for an instructor's physical presence. Video conference learning offers real-time learning services of video content. It is attained mostly remotely, with instructor's virtual presentations and the use of video-conferencing tools, remote electronic slides and interactive boards. Course material is usually placed on an LMS platform that offers to the learners the LMS capabilities which were mentioned previously. Video conference learning is a blended learning method which maintains the benefits of electronically assisted learning, while it tries to eliminate the traditional learning modes using audio-video, text to speech, speech to text and haptic technologies. It also incorporates smart agents which correlate the real-time instruction process with existing platform content and present that content to each user, based on questions, response and user profile preferences. Interactive services and agents can play a major role in video conference learning. They can offer a set of preloaded answers and content indications with the form of hints according to each user questions. Interactive services can also offer the capability of real-time feedback from the instructor, in case a question is not included in the pre-recorded questions database.

Video Instructed Learning: This learning process takes video conference learning one-step further by trying to revoke instructor's physical or virtual presence. It includes an LMS platform where the learners can log in and watch pre-recorded video courses. Learners can pose their questions using LMS forum capabilities, follow course Wiki reports and get examined remotely with the use of LMS examination board modules. This method is a blend of video conference learning that tries to skip out on the real-time instructor-learner knowledge transfer part. More advanced services of video instructed courses offer smart agents or bots that can present video suggestions according to the users' profile and learning path. They perform targeted search, pointing out, requested specific time slices of video information.

Ubiquitous learning (u-learning) aggregates the last three learning methods in a single LMS platform [7]. Ubiquitous learning is often simply defined as learning anywhere, anytime and therefore includes the means of mobility. U-Learning is also considered to be learning that is situated and immersive, and thus could take place from the traditional classroom in a virtual environment. The theory of ubiquitous learning is different from the other types of learning activity, since learners can continually move [8]. They learn across space, as they take ideas and learning resources gained in one location and apply or develop them in another. They learn across time, by revisiting knowledge that was gained earlier in a different context, and more broadly, through ideas and strategies gained in early years providing a framework for lifetime learning. They move from topic to topic, managing a range of personal learning projects, rather than following a single curriculum. They also move out of engagement with technology [9]. Learners equipped with personal devices, such as smartphones and tablets, can start to share learning experiences at home or outdoors with their formal education [10]. The theory of ubiquitous learning takes into consideration the mobile use of technology.

The u-learning platforms produce vast amount of tracking data [11] which reveals learners' interactions with course activities. This data can be analyzed in order to assess learners learning, as well as to discover course content quality and exploitation. This area of applied research is becoming known as learning analytics. Even if learning analytics are widely used for learner behavior and interaction analysis, there are only a few studies which focus on the course assessments through usage data.

In this study, we adopt and apply the eight unique features introduced by Laudon and Traver [12] by adapting and extending them to nine dimensions of u-learning. We also propose some indexes and metrics for the assessment of ubiquitous and interactive video courses and we attempt to map them with the presented u-learning dimensions. The proposed metrics are calculated for a case study in a higher education institute and the results are explained.

2 Basic Features of U-learning

Features of smart content delivery services [12] would be proved a useful startup point for the appliance of the key monitoring features of e-learning services. Furthermore, based on authors' previous research where the nine unique features of e-commerce to e-learning technology were adopted, this study slightly change their meaning so as to suit to u-learning, as it is depicted in Table 1.

In this study, we map some of the dimensions of u-learning technology with the proposed indexes and metrics. The indexes and metrics are used for the facilitation of the course usage assessment. Initially, some indexes can be mined such as the number of Sessions, Pages, Unique pages, using appropriate programs and agents e.g. Python programs and PHP agents. From these indexes, the metrics Enrichment, Disappointment and Interest which have been proposed in [13–18] can be calculated. In addition, some new metrics are proposed that are presented in brief in Table 2 and analyzed in detail at the next section. With the measures of Table 2, we quantify the offered educational material to the learners in terms of input variables for each course. The third column of Table 2, corresponds the proposed index/metric to the dimensions of u-learning of Table 1. It is worth mentioning that most of them were initially proposed and used by Laudon and Traver [12] in e-commerce. Six dimensions are examined in this paper: (i) *Reach*, in order to pinpoint if learning can be enabled across cultural and national boundaries seamlessly since u-learning can be applied anywhere without spatial restrictions; (ii) *Richness*, so as to discover if the content is adequate for u-learning; (iii) *Personalization/Customization* in order to discover if there is content in a course customized to the different types of learners since u-learning is open for every learner regardless their learning characteristics, (iv) *Social Technology* so as to gather learners opinion and participation virtual communities that u-learning can support; (v) *Knowledge Discovery*, to find out how often learners discontinue the learning and how easy is for them to discover the exact knowledge and learning content they want to study and (vi) *Interactivity*, since user interactions with the learning content are one of the most important characteristics of u-learning.

Table 1. Dimensions of u-learning technology and their education meaning.

U-learning technology dimension	Education meaning
Availability and mobility—Internet/Web technology is available everywhere: at work, at home, and elsewhere via mobile devices, anytime	The Learning place is extended beyond traditional boundaries and is removed from a temporal and geographic location. "Learning space" is created; learning can take place anywhere. Learner's convenience is enhanced, and teaching costs are reduced
Reach in the form of content formalization and internationalization—The technology reaches across national boundaries, around the world	Learning is enabled across cultural and national boundaries seamlessly and without modification. "Learning space" includes potentially billions of learners and thousands of schools worldwide
Universal content standards—There is one set of technology standards, namely Internet standards	Learning platforms can gain the advantages of the technological standards that can be exploited by the users
Richness and contained information density —Video, audio, and text messages are possible	Video, audio, and text messages are integrated into a single learning message and teaching experience
Interactivity—The technology works through interaction with the learner	Learners are engaged in a dialog that dynamically adjusts the experience to the individual, and makes the learner a co-participant in the process of teaching
Precise knowledge discovery—The technology reduces information costs and raises quality	Smart Information processing using data mining algorithms. Personalized learning paths can be applied for every learner
Content clustering and classification—Content organization and meta-tagging	Course content is organized and tagged appropriately in order for the search AI agents to deliver precise information to the end user
Personalization/Customization—The technology allows personalized messages to be delivered to individuals as well as groups	Personalization of learning messages and customization of services are based on individual characteristics
Social technology— Learner content generation and social networks. Social media feedback and content inclusion and characterization	New Internet learning models enable learner content creation and distribution, and support social networks

Table 2. Proposed LMS course evaluation metrics and mapping with u-learning features

Index/metric name	Description of the index/metric	Related dimension
Sessions (Visits)	The total number of sessions per course viewed by learners. It equals to course visits. It also includes geographical sessions placement and language options	Reach
All Pages	The total number of pages per course created by instructors for all LMS course modules	Richness
Unique pages	The number of unique pages per course viewed by learners. These pages are also called distinguished by course learner pages	Reach, Richness
Unique pages per course per sessions (UPCS)	UPCS measures the Unique pages per course per sessions delivered automatically by LMS content modules	Personalization/ Customization
Quality of Experience (QoE)	Is based on positive or negative opinion of users as reflected by Social forums. Measured by Social Technology modules using opinion mining algorithms	Social Technology
Enrichment (Enr)	Enrichment of courses (Unique pages/Pages) measures the number of times that unique course information is identified by course learners	Richness
Disappointment (Dis)	Number of sessions (visits) per course over the total added by instructor course pages. It reflects how often learners discontinue viewing course pages	Knowledge Discovery
Interest (Int)	It is the complement to the disappointment $\|1 - Dis\|$	Knowledge Discovery
Video Interactions Exploitation (VIE)	Is the number of interactions used by the learners in a specific course divided by the average number of learners interactions of all platform courses	Interactivity Customization

3 Proposed Metrics Analysis and Adaptation to U-learning

In this section, we extend and adapt some already adopted and evaluated metrics along with some new for the evaluation of u-learning and video courses according to learners actions over the educational platform.

The Unique Pages metric expresses the number of unique pages created or identified in an LMS platform as part of user-platform interaction. As a metric, it is presented as an aggregation of all recorded unique pages of a course over a period of time (Unique Pages per course). It is a measurement of interactivity services or smart agent content delivery over advanced user content mining.

The *Unique Pages per Course per Session (UPCS)* is a personalization and partly interactive metric that measures a cumulative sum of Unique pages per session generated as response from users advanced content requests. UPCS is a personalization metric that records the per sessions unique pages of suggestion or personalization content search modules. It is expressed as a cumulative metric of unique pages offered by those modules over a period of time. It is combined with the Personalization Depth (PD) index, in order to deliver a multiplicative metric of personalization content offered to the end users over a period of time.

The *Quality of Experience (QoE)* is based on positive-negative or attributable opinion mining of a course as pointed out by LMS chat, forum or social network modules (for example modules that connect to a Facebook course page). QoE is measured as the number of truly positive course opinions of a set of k message threads over the total (among those k) discovered messages as course opinions. That is L opinion set, subset of K messages:

$$QoE = \frac{\sum_{i=1}^{L} Positive\_Opinion_i Conf_i}{\sum_{i=1}^{L} Opinion_i} \tag{1}$$

Where confi is a p-value coefficient that expresses the confidence level for each positive opinion. Index confi is calculated either as the probability of a sentence similarity over a well-defined training dataset of positive course expressions or by performing a t-test under the hypothesis of a negative opinion and calculating the test p-value.

Enrichment metric is the metric that measures quantitative course characteristics and course content richness; enrichment metric expresses LMS course content enrichment as it is identified as content followed-visited by course users. LMS Enrichment metric is equal to the number of distinguished by users LMS course URI's over the total number of course URI's of the enabled LMS course modules. For example, let us assume two courses (A and B) with 100 pages similar course content each of them. Learners visited course A in total 30 course pages for a semester, while learners followed in total 50 pages of course B. This means that EnrA,B = 0.3 and 0.5 for courses A and B accordingly. This also means that course B has a richer full content as identified by course readers than of course A. Enrichment values can vary from $0 < \text{Enr} \leq 1$. The closer to value 1 is the course Enrichment value, the richer in terms of content the course is [19]. However, since Enrichment values do not cope with time variations, it is useful also to monitor per semester Enrichment variations. It has been recorded that some courses with a high Enrichment value on a semester, presented extremely low Enrichment values the semester that followed. This is due to course content deprecation, obsoleteness or users fed up with course instructor's contribution. We also propose a per semester detailed Enrichment metric recordings and justification of Enrichment variations at Table 3.

For the purpose of calculation of a total Enrichment value for a course the multiplication of all semester Enrichment values applies as:

$$\text{Total}_{\text{Enr}} = \prod\nolimits_{\text{i}=1}^{\text{n}} \text{Enr}_{\text{i}} \tag{2}$$

Table 3. Per semester enrichment variation table

Enrichment semester 1	Enrichment semester 2	Justification
$0.5 \leq \text{Enr} < 1$	$0.5 \leq \text{Enr} < 1$	High rich content of extreme value – still discovered and approved by course learners as of rich content
	$\text{Enr} < 0.5$	Deprecated course content, or course content updates have been abandoned by the instructor
$\text{Enr} \leq 0.5$	$0.5 \leq \text{Enr} < 1$	Course initially set as of no significant content that has been updated by the instructor and the instructor updates were approved by learners
	$\text{Enr} < 0.5$	Obsolete content (Traditional teaching methods are used by the instructor)

Video instructed learning systems VLMS (Video Learning management systems) include video files that course users can watch on demand. Each video file is a multimedia container of MP4 or 3GP format within most cases duration ten to fifteen minutes and a specified maximum duration of no more than 2–3 h in seldom circumstances. In our experimental scenario, these video files were split into ten-minute chunks. Each chunk was named with a different auto-increment URI name. The web service video player was playing each requested video course file chunks in the correct order and in a way transparent for the end user. So, for each VLMS course there was a number of course video lecture files (maximum 13 per semester- 1 file per course week lecture) that each file was comprised of a set of video chunks (10 min per chunk). Each video chunk is for the web service a distinguished web page D_i. For example, a course with 4 video files may have k1 chunks for video file 1 ($D_1, D_2, \ldots D_{k1}$), k_2 chunks for video file 2 and so forth. A course user may watch for a whole semester two video lectures out of four and in depth of t_1 ($t_1 \leq k_1$) video chunks for video 1 and t_2 ($t_2 \leq k_2$) for video 2, once or repeatedly. This means that the Enrichment metric is calculated as the ratio of distinguished video chunks over the total video chunks.

Based on the previous analysis the Enhanced Enrichment metric (EEnr) for the LMS system was modified according to Eq. 3:

$$\text{EEnr} = \frac{\sum_{\text{j}=1}^{\text{j}\to\text{n}} \text{DP}_{\text{j}}}{\sum_{\text{i}=1}^{\text{n}} \sum_{k=1}^{k_i} D_i} \tag{3}$$

Where n is the number of course learning objects and D_i are their learning object files. DP_j is the number of distinguished learning objects ($j \leq n$, usually j = 1..n), where for each learning object the average semester user files viewed is calculated and then median for all users. For m course users DP_j is calculated based on Eq. 4:

$$s\,DPj = \begin{cases} \frac{\overline{k_J}+1}{2}, & modd \\ \frac{\frac{\overline{k_J}}{2}+(\frac{\overline{k_J}}{2}+1)}{2}, & meven \end{cases} \quad (4)$$

Where is the number of times for a semester period that each user viewed a specific course learning object and is calculated according to Eq. (5):

$$\overline{k_j} = \frac{1}{nw}\sum_{w=\mathbf{1}}^{nw} D_w, \text{ w} = 1..\text{nw} \quad (5)$$

In Eq. 5, D_w represents the number of files that each user viewed each time s/he accessed the specific learning object.

Summing up, $\overline{k_j}$ expresses the per learning object per user average number of files viewed per semester period. DP_j (j corresponds to the j^{th} learning object of the course) is therefore the median $\overline{k_j}$ value identified by all course users. The number m of course visitors can be calculated by the LMS platform, since it monitors closely user.

Video Interactions Exploitation (VIE) is a metric that attempts to measure the rate of utilization of interactions in a video divided by the average use of interactions in the video courses of the platform. Each video course and platform supports specific types and numbers of interactions. When the learners watch a video may exploit, or not, the provided interaction types such as annotations, comments, hyperlinks, video summarization etc. This metric gives a brief view of the exploitation of these interactions by the learners. However, this metric has a limitation regarding the video length. For example when a course has only a 3 min video and another course has videos of 3 h total length, it is obvious that learners may interact more times with these videos. Therefore we propose the *Enhanced Video Interaction Exploitation (EVIE)* which takes into account the provided video size, that is related with the video length, with the assumption that the videos' quality is similar, and is calculated according to Eq. 6:

$$EVIE = \frac{\frac{Int_i}{TVT_i}}{\frac{1}{n}\sum_{v=1}^{n}\frac{Int_v}{TVT_v}} \quad (6)$$

where n is the number of the courses, i is the number of the specific course, Int is the number of interactions made by the learners in a course, TVT is the Total Video Time of a course. The EVIE justification, regarding its potential values, is presented at Table 4.

EVIE corresponds directly to the Interactivity dimensions of the features of U-learning.

Disappointment metric is equal to the number of course visits over the total number of pages-URI's of the enabled LMS course modules added by the instructor. Disappointment is an interesting metric, and it is important to have value greater than 1. Disappointment course visits are calculated on a weekly or monthly basis and are therefore characterized as weekly course visits and not as semester course visits (Disappointment course visits counter is reset every week or month). E.g. if weekly course visits for a course A are less than course pages (Dis $\leq$ 1), this means that the learners showed their strong weekly disappointment regarding course content. If weekly course visits are more than course pages then it is an indication of an interesting course weekly content.

Table 4. EVIE variation table.

EVIE	Justification
EVIE <= 056	Video interactions slightly used
0.5 $\leq$ EVIE = $\leq$ 1,5	Video interactions used by the learners in an ordinary way
0.5 $\leq$ EVIE	Learners exploit in depth the provided video interactions

The total semester course Disappointment metric value is calculated as a mean value according to Eq. 7.

$$\mathrm{Dis} = \frac{1}{\mathrm{w}} \sum\nolimits_{\mathrm{i}=1}^{\mathrm{w}} \mathrm{Dis}_{\mathrm{i}} \tag{7}$$

where w is the number of semester weeks. There is a false-error indication at the measurement of Disappointment metric in some courses especially in the first semester weeks. In the first weeks of the semester, the course pages that are enabled are usually less than course visits (Initialization or course startup, erroneous Disappointment metric values spotted). This measurement exception has been handled with the use of a monthly startup Disappointment measurement interval followed by weekly measurement intervals.

Disappointment metric recordings and justification of Disappointment variations are shown at Table 5.

Enhanced Disappointment (EDis) metric for a VLMS platform is calculated using Eq. 8, as the number of platform authenticated visits multiplied by a parameter called AVT (Average Visit Time) and is calculated in minutes (expressed the total session visit duration from logging in, to logging out the LMS platform), over the total content in terms of pages/images and/or video time of all recorded video files in minutes.

$$EDis = \frac{\sum AVT}{\sum\nolimits_{\mathrm{i}=1}^{\mathrm{n}} T_i} \tag{8}$$

where Σ is sum the weekly VLMS visits, AVT is the weekly average usage duration of the LMS platform) and $\sum\limits_{i=1}^{n} T_i$ is the total course pages, images and video duration time.

If $\frac{VAVT}{\sum\nolimits_{\mathrm{i}=1}^{n} T_i} < \leq \sum\nolimits_{i=1}^{n} T_i$ then the EDis $\leq$ 0.1. This means that the corresponding course is less visited and/or followed by users on a weekly basis.

However if $\frac{VAVT}{\sum\nolimits_{\mathrm{i}=1}^{n} T_i} \gg \sum\nolimits_{i=1}^{n} T_i$ then EDis $\gg$2, thereafter the corresponding course is a highly visited followed and appreciated by course users.

Table 5. Per semester disappointment variation table.

Disappointment Week n−1	Disappointment Week n (n < 13)	Justification
$0.5 \leq Dis \leq 1$	$0.5 \leq Dis \leq 1$	Course of low interest and low interest progress over time
	Dis > 1	Course that was slow started with a low interest and participation, but latter on managed to focus learners interest and participation
Dis < 0.5	$Dis \leq 1$	Course where Electronically assisted learning methodology is not used or applied whatsoever. Possibly Traditional learning methods used by the instructor
	Dis > 1	Course of initial low interest that the instructor enriched (Definite Enr increase) its content and therefore increased significantly users interest
Dis > 1	$0.5 \leq Dis \leq 1$	Course of initial high interest that in time learners disapproved its significance and instructor's contribution and therefore the course has shown a lack of learners' interest (possible Enr decrease)
	Dis > 1	Course of extremely high interest over time

The total semester course EDis metric value is calculated as a mean value as it represented in Eq. 9.

$$\mathrm{EDis} = \frac{1}{w}\sum\nolimits_{i=1}^{w} \mathrm{EDis}_i \tag{9}$$

The *Interest metric (Int)* expresses the learners' interest regarding a course. If Int $\leq$ 1 then the course is a noninteresting course of low weekly number of visits, while of Int > 1 then the course is an interesting course and is visited by learners on a weekly basis. The higher the interest value (Int $\gg$ 1) the more interesting the course is.

Interest and EInterest (Enhanced Interest) metrics calculation were initially performed using the |1-Dis| or |1-EDis| formula for the calculation accordingly. Although these formulas represent Interest as a complement of Disappointment metrics values, however in both cases it fails to represent correctly Interest and Enhanced Interest values. For example, when the values of EDis (or Dis) range is between [0..1], the EInt values are between [−1..0], while when EDis values are above 1, EInt value is linearly expresses −Dis. Such metric response does not cope with the non linear experimental results between course visits (that are highly correlated to Interest) and course disappointment metric. For that purpose, based on the experimental results, authors modify the Interest metric calculation from Disappointment metric values using a close to a logistic regression curve expressed by Eq. 10, which fitted the experimental results between Visits and Disappointment. According to Eq. 10, calculated EInt is bounded to a maximum value of 1.5. For Dis or EDis $\geq$ 0.4, Interest values are greater or equal to one (1 $\leq$ Int or EInt < 1.5) and for 0 < EDis < 0,4, EInt metric values are: 0.1 $\leq$

EInt < 1. This means that Eq. 10 maintains Interest-EInterest metrics expressions in terms of metric values.

$$Int = \begin{cases} 0.5 + \frac{1}{0.01 + 2^{\frac{1}{Dis^2}}}, & Dis \geq 0.4 \\ \frac{1}{0.01 + 2^{\frac{1}{(0.5 + Dis)^2}}}, & 0 \leq Dis < 0.4 \end{cases} \tag{10}$$

4 Experimental Scenario

The experimental measurements took place at the winter semester of 2015–2016. We analyzed the data from the 10 most active courses of the Department of Accounting and Finance in TEI of Eastern Macedonia and Thrace. More than 2000 learners study in the department but they are not all active in the LMS. The institute offers e-learning as a supplementary mode. The department uses the Open eClass e-learning platform [19]. We tried to correspond the data analysis results to the unique features of u-learning. We present the results of the data analysis to the course instructors, asking for their comments on the research conclusions in Table 6. In particular, we chose the 10 courses that had the higher activity. The values of the indexes and metrics of the collected data, at the end of the semester, are recorded.

Table 6. Measures of the indexes and metrics

C#	AP	P	UP	EEnr	EDis	EInt
C1	29	342	26	0,897	11,793	1,485
C2	37	179	36	0,973	4,838	1,461
C3	33	184	29	0,879	5,576	1,468
C4	18	216	16	0,889	12,000	1,485
C5	38	326	36	0,947	8,579	1,480
C6	41	260	36	0,878	6,341	1,473
C7	40	241	37	0,925	6,025	1,471
C8	34	284	30	0,882	8,353	1,480
C9	32	318	28	0,875	9,938	1,483
C10	33	268	29	0,879	8,121	1,479

C#: Course Number, AP: All Pages, P: Pages, UP: Unique Pages

The results indicate high scores for EEnr since the values are close to 1. EDis has also high values which is explained, according to Table 5 that the course has high interest over time.

Additionally, the results present interesting findings in terms of Enrichment, Disappointment and consequently, reach and richness.

The courses C2, C5 and C7 appear with remarkable high Enrichment since they have the largest values in EEnr. Indeed, when we analyze the content of these courses, we discovered that they had an organized structure and provided a lot of useful educational content.

The courses C4, C1 and C2 appear with high Disappointment since they have the largest values in EDis. It is worth mentioning that high values of the metric Disappointment correspond to courses of low interest.

The above results presented in detail to six instructors of the specific courses and a semi-structured interview took place. Two of the researchers explained to the course authors the concept behind each metric, what each value represents and their courses ranking, along with their corresponding dimensions of u-learning.

A discussion took place about the accuracy of the research results. The instructors generally agree with the findings of the experiment; however, two of them pointed that the structure of the platform does not allow them to reveal safe outcomes. We agree with the instructors, since the adopted platform (E-Class) does not allow them to easily upload data directly and most of the times, they upload documents (pdf, docx, pptx etc.) which learners study offline. Therefore, it is not possible to take into consideration this part of their study. Two other instructors pointed out that it would be useful if we analyze learners' grades in the specific courses, and directly acquire their opinion through a questionnaire, in order to validate the efficiency of our method. They believed that the proposed metrics could be an efficient tool, which can help authors improve their courses content in terms of quality and quantity.

5 Discussion and Conclusion

This study initially introduces u-learning and proposes some indexes and metrics for the assessment of online courses and videos. An approach for measuring through indexes and metrics was presented; features that Laudon and Traver [12] proposed for use in e-commerce and the authors adopted and adapted them for use in ubiquitous learning. These metrics were applied in ten online higher education courses and the results revealed their characteristics in terms of learning dimensions. It differs and contributes by changing the existing seven ones and adding two more features suitable for learning.

The results were discussed with six of the course authors and their feedback was positive about the proposed indexes and metrics. They were asked to improve the quality and quantity of their course material taking into consideration assessment results. This process and course ranking seems that it triggered teachers' interest and motivate them to improve their courses, in order to be at the top of the rankings.

However, there are some limitations of this study. The sample number of courses and number of learners is low. In addition, the adopted platform did not provide interactive video features and the proposed EVIE metric was not calculated at the experiment. Also, the research was conducted in only one department for just one semester. Therefore, we plan to repeat the study with a new larger sample. It will also be beneficial, if current study procedures could be applied in other universities and platforms, in order to confirm the findings of this study. We also plan to assess the first U-learning technology dimension, the availability and mobility of the courses with specific metrics that will measure these features.

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The Use of Computational Tools in Mathematics Teaching for Visually Disabled Students: An Analysis of the Brazilian Context

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Abstract. Suitable computational tools can provide more autonomy for visually disabled students, especially in more advanced levels of education. The use of technological resources contributes to equality in access to mathematical information for sighted and visually disabled students. The aim of this study was to map existing research in the context of master's and doctoral post graduate studies developed in Brazil, addressing the use of technology for teaching mathematics for blind and low vision students. Studies about the use of computational tools as an aid to teaching people with visual impairment are still very recent in Brazil. The study in this paper examined the mathematical content approached, the computational tools used, time of the publication, degree level and geographical distribution of the studies in Brazil. This study enabled us to conclude that existing tools are mostly focused on teaching basic mathematical concepts such as fundamental operations, flat geometry, and initial algebraic formulations. However, we noticed a lack of studies focus on secondary and higher education. In addition to broadening the dissemination of existing studies and tools, it is necessary to re-evaluate teacher training. The gaps reported in the present study may provide good relection and directions to further develop tools for the visually-disabled students in Maths classes.

Keywords: Computational tools · Visually disabled students · Brazilian post graduate studies · Mathematics

1 Introduction

According to the World Report on Disability [21], every 5 s, 1 person becomes blind in the world. In addition, of the total blindness cases, 90% occur in emerging and developing countries. It is estimated that, by 2020, the number of people with visual impairments may double in the world. Of the total Brazilian population, 23.9% (45.6 million people) reported having some kind of disability [22]. Among the declared disabilities, the most common was the visual, reaching 3.5% of the population. Then there were motor problems (2.3%), intellectual (1.4%) and hearing (1.1%).

According to data from the 2010 Census by IBGE [22], Brazil has more than 6.5 million people with some visual impairment. Among these people, 528,624 are unable

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to see (blind) and another 6,056,654 people have low vision (serious and permanent difficulty to see) [1].

Considering school period, it is very important to ensure that each of these people has adequate access to basic and higher education. In addition, it is necessary to ensure that equity conditions for all students are guaranteed, including access to all teaching tools [2].

The teaching of subjects in the field of exact sciences can be a major challenge for blind students or students with some kind of visual disability. The mathematical symbology and graphic resources involved can be very difficult to interpret even for sighted students [3]. In the case of students with visual disabilities, the lack of adequate tools to access this type of information may undermine the equality of rights. Thus, these students may be constantly at a disadvantage in the exact sciences, because the graphical information is not always in accessible formats [4], as most content often relies on visual notations [19], in addition to teachers not always being familiar with adequate teaching resources.

However, in developing countries such as Brazil, factors such as the poor quality of teaching in general, limitations of infrastructure, lack of training of professionals and lack of information of students with disabilities contribute to an unsatisfactory inclusion process. Thereafter, Brazil presents research data and availability of more incipient resources when compared to other countries.

In Brazil, most studies on teaching methodologies for people with visual disabilities have focused mostly on the use of manipulative materials. This is the main resource used in basic education. However, although fundamental, manipulative resources need to be complemented by others tools for access to mathematical formulation and graphical interpretation. The world of computational resources has opened up new ways of communication for blind people. Screen reader programs are able to translate text on-screen into spoken words using speech synthesizers. In this case, screen readers and computational tools are key features for a visually disabled student. Unfortunately, within the Brazilian context, the studies about teaching Mathematics using computational resources are still scarce. Furthermore, as mentioned by Jackson [20], "unfortunately, these programs generally do not work well with text containing mathematical symbols, and some blind mathematicians tend to use the programs only for reading email or surfing the Web (which is becoming more complicated for the blind due to the heavy use of graphics)".

Despite the limitation in the number of studies about the use of technology in Mathematics education for blind students, it is necessary to obtain an overview and a critical analysis of research conducted in Brazil, considering a local level. With this, it is possible to position the focus of current efforts and research gaps from a broader perspective of the research efforts within curricular aspects and the needs of visually-disabled students.

Thus, the aim of this study was to map existing research in the context of master's and doctoral post graduate studies developed in Brazil, addressing the use of technology for teaching Mathematics to blind and low-vision students. From this mapping, it was possible to study the teaching levels, the types of skills and competences developed in pedagogical interventions, to analyze the types of technological resources used, the geographical origin of the studies, the application of the technologies used and the profile of the research participants.

This paper is organized as follows: (I) Introduction (II) Mathematical competences skills for people with visual impairment: Brazilian educational context. (III) Methodology (IV) Results (V) Conclusions.

2 Mathematical Skills for Students with Visual Disabilities: The Brazilian Education Context

The Brazilian basic education system is divided into three stages: Early Childhood Education, Elementary Education and Secondary Education. The Early Childhood school comprises the age group between 0 and 5 years, the Elementary Education period ranges between 6 and 14 years, and the Secondary Education the age group ranges between 15 and 17 years old [5].

The Early Childhood Education must represent the foundation of the education, aiming at the development in the physical, intellectual and social aspects of the child, complementing the actions of the family and the community [6]. The Elementary Education aims at the essential training of the citizen, having as basic means the full mastery of reading, writing and calculation. Consequently, Secondary Education provides for the consolidation and deepening of the knowledge acquired in Elementary Education, the basic preparation for the exercise of citizenship, training for work and further studies.

During the 1960s and 1970s, Mathematics teaching was influenced by a movement of renewal that became known as Modern Mathematics [6]. This influence was felt not only in Brazil, but also in other countries. Modern Mathematics was born as an educational movement inscribed in a policy of economic modernization and was put on the front line of education. Mathematics was constituted as a privileged access route for scientific and technological thinking. The Modern Mathematics tried to approach the Mathematics developed in the school of Mathematics as it is seen by researchers.

This line of thinking contributed to the fading between the Mathematics taught in school and the Mathematics of students' daily lives. Currently, there is an educators' effort to rescue a view of Mathematics which would be more practical and real for students.

In 1980, the US National Council of Teachers of Mathematics (NCTM) presented a document with recommendations for teaching Mathematics for the different school levels. The paper addressed problem solving as the focus of Mathematics teaching. In addition, it also addressed the understanding of the relevance of social, anthropological, linguistic, as well as cognitive aspects in the learning of Mathematics.

However, the practical Brazilian reality does incorporate deeper topics related to problem-solving and more intricate cognitive aspects in the learning of Mathematics. According to the National Curricular Parameters [7], as early as in 1997, among the obstacles that Brazil has faced in relation to Mathematics teaching, there is a lack of qualified professional training, restrictions related to working conditions, lack of educational policies and misinterpretations of pedagogical conceptions. The performance on international exams and the perception of teachers suggest that this is still the reality. Still, many efforts have been undertaken to minimize these problems.

Among the efforts for this improvement, the recommendation of the use of didactic resources, including some specific materials, is made in almost all Brazilian curricular proposals. Unfortunately, the use of these materials is not always adequate, either due to the lack of school structure or due to the lack of teachers training.

Thus, the teaching of Mathematics in Brazil ends up acting as a social filter during Elementary School, with poor students having a lower performance and higher rates of high school failure. Secondly [7], these rates end up selecting the students who will or will not have the opportunity to complete this segment of education.

Within this reality, the inclusion of students with some type of disability becomes a great challenge for the Brazilian educational system. Historically, this discussion began at the UNESCO World Conference on Education for All in the 1990s. The aim of the Conference was to provide for an inclusive school that respected the diversity of students, including those with special needs.

In 1994, the leaders of 84 countries, including Brazil, met in Salamanca, Spain, for the World Conference on Special Needs. In this way, the Declaration of Salamanca was created [23]. Its objectives were the recognition of students' differences in educational attendance, teacher training, and the support of a school for all.

In 2001, the Brazilian Ministry of Education presented the "Special Guidelines for Special Education in Basic Education" [18]. The document was created in order to guide inclusive education in the country. The document's objective is focused on the development of specific contents to attend to students with disabilities and the operationalization of teaching.

Thus, it is a right of the student with disabilities to be inserted into the current educational system, "without distinction of linguistic, sensory, cognitive, physical, emotional, ethnic, socioeconomic or other conditions" [8].

Despite the inclusion in education being a right guaranteed by law [2], students with disabilities still have to face major challenges during the school life. Teachers report the scarcity of adapted textbooks and manipulative materials. Many of the materials are produced creatively by teachers themselves, immersed in the reality of their students. Students with visual disabilities report that the impediment to learning is not properly the complexity of mathematical content, but the adequacy of the material, the shortage of resources, and how mathematical concepts are approached by the teacher [8].

Thus, suitable computational tools can provide autonomy for students with visual disabilities, especially in more advanced levels of education. The use of technological resources contributes to equality in access to mathematical information for visual and visually disabled students. Existing resources, such as appropriate screen readers, software with auditory resources for learning geometry and algebra, or the union of manipulative materials and computational resources are fundamental tools for the inclusion process to be really effective.

3 Methodology

3.1 Research Design

Considering the Brazilian context, most of the scientific and technological advances are developed within universities and postgraduate programs. Therefore, for this study, a review of master's and doctoral studies developed in Brazilian postgraduate programs was carried out. The selected works discuss the application of computational tools for teaching Mathematics to people with blindness or low vision.

This secondary data collection allowed for a broader perspective of the context of teaching Mathematics for people with visual disabilities within the local reality. The studies were selected in the Brazilian portal of theses and dissertations of CAPES.

CAPES (in Portuguese: Coordenação de Aperfeiçoamento de Pessoal de Nível Superior) is a foundation linked to the Brazilian Ministry of Education (MEC), which works to expand and consolidate master's and doctoral programs in the country. This foundation is responsible for periodical evaluation of all Brazilian postgraduate programs. In addition, the foundation contributes to the development of Brazilian research through the Thesis and Dissertation Catalog (in Portuguese "Catálogo de Teses e Dissertações"), in which institutions of higher education, research institutions, state and municipal public higher education institutions participate publishing the studies, all evaluated by CAPES. This website is the broadest collection of post-graduate studies to survey data on Brazilian's thesis and dissertations.

3.2 Studies Selection

To understand the landscape of teaching Mathematics to visually disabled people in the Brazilian context, the portal of CAPES was accessed in the period between December 2017 and January 2018. The objective was to select master's dissertations and doctoral theses concerning the use of computational tools to teach visually disabled students.

The keywords used in the search were "blind", "blindness" and "visual disability", with refinement of research for the areas of "Teaching", "Mathematics" and "Interdisciplinary". The search was performed in Portuguese.

The search was done in such a way that results were as complete as possible, covering studies about resources for teaching Mathematics for visually disabled people. The keyword "Computational tools" was not used in the embracing search.

In this first search, 146 papers were found dealing with the teaching of Mathematics and Science for people with visual disabilities, including all levels of school organization. From this result, the abstracts of each work were read, with the objective of identifying the works that dealt with "Mathematics Teaching" and "Computational Tools". Thus, of the total of studies found, only 6 works specifically dealt with computational resources for Mathematics teaching for visually disabled people. This is a worrying reality, given the need to include this student profile in the common curriculum of Brazilian schools. The complete analysis of these studies is shown in the results session.

3.3 Data Analysis

After surveying the use of technologies to teach people with visual disabilities, the data obtained were analyzed using the thematic analysis methodology, suitable for the study of qualitative data [9].

For this purpose, the analysis topics were defined and the studies were classified in the following categories: (a) Year of the study; (b) Brazilian region in which the study was developed; (c) Degree level of study (master's or PHD); (d) Students school level; (e) Mathematical content that was worked and (f) Computational tool used.

The classification in categories provided an overview of Brazilian context of mathematics teaching math for visually impaired people. In addition, it also made it possible to identify the research gaps in this subject.

4 Results

After listing the Brazilian postgraduate studies on the use of computational resources to teach mathematics for visually disabled students, the information was analyzed as follows: chronological analysis by region and by type of work, classification according to target audience and analysis of tools used and results obtained by the works. These categories were discussed within the Brazilian educational context. Table 1 shows a synthesis of the six graduate studies developed in Brazil.

Table 1. Summary of post graduate research studies on the application of computational resources in teaching persons with visual disabilities.

Post graduate research studies	Objectives	Results	Degree level	Topic	Computational resource
Lírio [11]	To know the possibilities and limitations of the use of computer technology for teaching geometry to blind students	The students were able to construct several flat geometric figures and the VOX Drawing software presented itself as an educational resource that has much to contribute to the improvement of care for the visually impaired	Master's degree	Plane geometry	DOSVOX drawing
Martins [12]	To investigate math learning in blind people and people with low vision	Starting at their interactions with the software, the subjects identified different	Master's degree	Numerical representation/ fractional numbers	Software musiCALcolorida

(*continued*)

Table 1. (*continued*)

Post graduate research studies	Objectives	Results	Degree level	Topic	Computational resource
	through sound signals emitted by software	decimal number representations (exact, periodic, simple or compound) guided just by the sound			
Santos [13]	To adapt a virtual learning environment to make it accessible to people with sensory limitations (blind and deaf)	Discursive typologies were identified that allowed to point out the emergence of argumentative networks in the discussions around the solution of one of the problems	Master's degree	Basic mathematical operations and logics	Virtual learning environmental
José Santos [14]	To elaborate a tool capable of creating a dynamic representation of the graph of a real polynomial function of the first degrees that blind or low vision students could interact with others students and the teacher	The authors developed a plotter and a computer program that allows for three forms of representation functions: graphical, tabular and algebraic	Master's degree	Graphical representation of first degree functions	Screen reader and manipulative material
Prado [15]	To analyze the contributions of teaching strategies developed in the Multifunctional Resource Rooms for the mathematical learning of blind and deaf students in the city of Rio Branco - Acre, Brazil	Assistive technologies adopted are not adequate, mainly for the contents for more advanced series	Master's degree	Basic mathematical operations	Screen reader
Calixto [16]	To analyze the contributions of teaching strategies developed in the Multifunctional Resource Rooms for the mathematical learning of blind and deaf students in the city of Rio Branco - Acre, Brazil	Reflection about the opportunities of mathematical learning of blind and deaf students mediated by the teaching strategies and by the specific adaptations their disabilities in the presented environments	Master's degree	Basic mathematical operations	Screen reader

4.1 Chronological Analysis, Analysis by Geographical Region and Analysis by Degree Level Study

Studies about the use of computational tools as an aid to teaching people with visual disabilities are still very recent in Brazil. We can note that the oldest work developed in a postgraduate course in Brazil dates from the year 2006. The results organized according to the year of obtaining the author's degree are shown in Table 2. One justification for this is that the approach to inclusive education is quite recent in teacher's education in Brazil [10].

Table 2. Number of Brazilians studies developed per year.

Year	Number of studies
2006	1
2010	1
2012	2
2013	1
2015	1

The next study was defended only four years later in the year 2010. After that, there was a reduction of one to two years in the time interval between the defenses. The time interval shows the shortage of developed studies, despite the social importance of the object of study.

The organization of the work by geographic region is shown in Table 3. It is very interesting to note that, with regard to the region where the works were developed, the Brazilian region with the greatest scientific impact is the Southeast. This fact could be justified by the great concentration of universities in this Brazilian region. However, of the four works performed in this region, three were developed in the same university. It can be concluded that graduate studies in this area are concentrated in few university centers, despite the fact that the region has a greater diversity of institutions than elsewhere in the country.

Table 3. Number of Brazilians studies developed per geographic region.

Geographic region	Number of studies
North	1
Northeast	1
Center-West	0
South	0
Southeast	4

According to the 2010 census [22], the Southeast region is the Brazilian region with the lowest percentage of visually disabled people in Brazil, or 3.1% of the local population. However, the Southern concentrates most of the postgraduate studies on the subject in the country. These data show that Brazil has few developing postgraduate research in the area. In addition, there is concentration of work in isolated groups. It can be concluded that there is little or no transfer of knowledge between programs.

The Northeast region is the region with the highest percentage of the population with visual impairment in Brazil. Even so, the only work developed in this region is still quite recent.

In the Center-West and South regions of the country, no graduate study on the subject was developed. Put together, the populations of people with some type of visual disabilities residing in these regions correspond to 6.2% of the local population. No post-graduate studies were completed until now in these regions regarding the topic.

The North region of Brazil, which has 3.6% of the local population with some type of visual disability, has one master's dissertation concluded. Comparing the North region with the Central West and South Regions, and taking into account that the North region has a smaller number of university centers, the result shows that the studies in the area have a relevant role within the Brazilian context.

All the post graduate works developed in Brazil about the use of computational tools to teach mathematics for people with visual impairment are master's studies. This shows how much the field of research in the country is recent and is taking the first steps towards the effective use of technologies for the teaching of mathematics for the visually impaired. This also shows that there needs to be greater interest in the topic for deeper studies developed at doctoral level.

4.2 Classification by Students School Levels and Mathematical Topics

The school levels analyzed by the studies found are shown in Table 4. Most of the studies cover content related to Elementary and Secondary Education. Only one study using computational resources for University Education was found. No study was found on the use of computational resources for visually-disabled children at Early Childhood Education.

Table 4. Number of postgraduate studies according students school levels.

Students school level	Number of post graduate studies in school level
Early childhood education	0
Elementary education	5
Secondary education	5
University education	1
Early childhood education	0

The results from Table 4 show the scarcity of use of computational resources for teaching students with visual disabilities in Early Childhood Education and University Education. This lack could be justified in children's education, taking into account that it is the mathematical literacy phase, and that playfulness can be found in manipulative materials suitable for the introduction and development of mathematical thinking. Nonetheless, there is a significant loss in the lack of studies in the use of computational resources in this stage. Furthermore, at University Education, when the entire basis of mathematical thinking should already be developed, studies on the application of computational resources in education should appear in greater numbers in Brazil. The lack of studies focused on this level of teaching may be a consequence of reports of the scarcity of efficient of computational tools for mathematical language. Teach math to this public demands suitable screen readers of formulas and mathematical symbology, for example [8].

4.3 Analysis of Computational Tools and Post Graduate Brazilian Studies Results

Most postgraduate studies published in Brazil use systems with screen reader resources as support in mathematics teaching. Based on the chronological analysis of the studies found, the oldest work, dating from 2006, uses the Vox Drawing tool, which is part of the free DOSVOX system. The VOX Drawing is a tool that allows the mathematical graphical expression through the geometric constructions. The most recent studies found, dating to 2013 and 2015 [15, 16] also use software based on screen reading capabilities. All tools used in the studies found are features available for free download. DOSVOX is a separate system, running on Windows, which has a speech synthesizer, but only executes its own applications. For example, it does not support reading of Word, but only of “CartaVox”. It was developed at a time when there was little availability of general-use screen readers in Portuguese in Brazil. However, despite its limitations due to not being a general-use screen reader, the systems developed to its platform still grant it a substantial use in Brazil.

Still about study [13], the VOX Drawing was applied for plane geometry teaching for Elementary school students. Through a qualitative methodology based on teaching experiments, the software was used in interaction activities between the researcher and two blind students. The results of the study showed that students were able to construct several plane geometric figures, such as squares, rectangles and triangles, after familiarizing themselves with the commands of the VOX Drawing program. This provided the visually disabled students with the possibility to apply the graphic expression of mathematical ideas.

The computational construction of the geometric structures was only possible after the students were familiarized with the location of points in the Cartesian plane and, mainly, with the representation of the figure through a model that can be explored with the hands. The successful work was the result of a combination of manipulative resources and computational resources, motivating the students in question.

Although screen readers are the most used computational resource in Brazil, there are still limitations of functioning regarding the teaching of mathematics for people with visual impairment. An important conclusion from Prado [15] is that screen readers, while important to the visually disabled student, still have many problems with regard to reading mathematical symbology. In addition, students in the more advanced series who participated in the research highlighted the importance of teacher training, to better carry out the studies. It is critical that the teacher be prepared to work with the available tools. This ensures that the use of these tools is as successful as possible.

There are research studies in progress in the country with the objective of developing specific tools for reading symbology and mathematical formulation in Portuguese language [17]. However, up to now, no post-graduate study about developing tools for reading formulas applied directly to teaching has been completed in the country.

The tool used by Martins [12] was a piece of software in calculator format, in which each number is represented by a different color and sound. The calculator, called MusiCALcolorida, can be used for visually disabled or deaf students. The research using this tool involved 8 participants: six adolescent from an institution specializing in the education of blind or partially-sighted persons and 2 adult volunteers. Data analysis indicated that, from their interactions with the MusiCALcolorida software, the subjects identified different decimal number representations (exact, simple periodic or compound) guided only by sound.

Indications of a process of objectification in which the sound of the calculator became more than a simple music, being incorporated as a symbol of the studied mathematical object, were observed in the activities developed in this study.

The use of virtual learning environments is also recent in teaching mathematics for the visually impaired. In 2012, Lirio [11] created a virtual learning environment adapted for blind university students to solve problems related to basic mathematical operations and logics. The initial proposal was that there could be collaboration between the participants, but this did not happen as expected. Although the subjects of the research had affinity with computers, the networks of discussion were not satisfactory.

In the same year, in 2012, Santos [14] developed a mechanical tool combined with the use of software called Sensory Plotter. By using the Sensory Plotter, students could modify the algebraic formulation of first degree functions computationally. Through a manipulative device, changes in the graph of function made computationally could be felt by the student's hands through touch. Thus, students could feel the influence of the modification of function coefficients on growth, decrement and slope in the function graph. Some limitations that were perceived during the tests, such as slowness in the software sound feature, shortcut keystrokes to perform procedures, lack of Braille identification in the sensory part of the equipment, and excessive size of the sensory plotter. Despite the difficulties encountered by the research students, the plotter provided access to the mathematical concept of functions by blind or low vision students.

In all postgraduate studies found, taking into account the time interval of twelve years, it can be verified that the majority of the studies is concentrated in the understanding of the basic mathematical operations, concepts of logic and basic concepts of polynomial function.

Considering the organization of the Brazilian educational structure, the mathematical concepts addressed in the dissertations found only cover the content worked in elementary school. These concepts are theoretical basis for mathematical deepening during high school. Computational resources are lacking for teaching more advanced mathematical formulations.

The small number of post graduate studies about the use of computational resource for teaching visually disabled students shows that the use of manipulative resources still predominant in research in Brazil. However, in view of the current technological panorama, not using computational resources as a mediating tool can be a great limitation in the process of teaching Mathematics. There is a great need to discuss the efficiency of tools for screen readers for more advanced algebraic notation, for example.

In the current Brazilian context, students who want to pursue a career in field with strong connections to exact sciences, for example, are totally dependent on teaching assistants who can be their readers and note takers and writers. This is caused by the lack of adequate computational resources, as well as the need to train teachers and students to better use these resources. Although it is a right of the visually impaired student to be accompanied by a reader/writer, the scarcity of adequate computational resources for mathematical language impairs the autonomy of this student throughout his academic and academic life.

5 Conclusions

The observation of this panorama on teaching of Mathematics for people with visual disabilities using computational resources shows that there is still a long way to be covered by Brazilian research.

The small number of postgraduate studies in the area shows that research and teaching centers needs to focus on improving the use of existing teaching tools, besides de development of new tools. All the studies found are master's dissertations. In addition, there is a need for greater interaction among research groups so that these tools are widely disseminated by society. Graduate studies are still heavily concentrated in the southeastern region, the most developed in the country, but not the region with the highest percentage of the population with visual disabilities.

In addition to broadening the dissemination of existing studies and tools, it is necessary to re-evaluate teacher training. Brazilian studies show that this professional is not always properly trained to use accessibility tools to visually disabled students. Moreover, most of the post-graduate studies in this area aimed at students in elementary education and higher education is still derisory. Existing tools are mostly focused on teaching basic mathematical concepts such as fundamental operations, flat geometry, and initial algebraic formulations. No work focused on topics with notation used in higher education was found.

Furthermore, it is necessary to contribute to the research and development of new computational tools specifically aimed at teaching mathematics. The most used tool in the Brazilian context is the screen readers. These tools have a satisfactory performance for reading ordinary text. However, the readers do not perform well in reading mathematical symbologies and specific formulations, particularly for the Portuguese language in the Brazilian variation. This limitation impairs the autonomy of the blind students in the most advanced series, making it dependent on a support monitor that can read and write for them.

Encouragement to fill in the research gaps found may provide appropriate tools for the visually impaired student in math classes. Consequently, the effective teaching of this discipline can bring autonomy, providing that the student is actually included in the Brazilian school context.

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From Expert Consulting to Co-creation in Medical Education; Co-creating an Exploratory Educational Space for Orthopedic Medical Education

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Abstract. Medical education is increasingly turning to technology enhanced learning for facilitating the learners' understanding of difficult concepts and honing the decision making skills of future healthcare professionals. Experiential digital content creation for medicine faces the challenge of keeping up with the rapidly growing volume of medical knowledge. A suggested avenue for addressing this challenge is the use of co-creative methodologies in order to engage the expert medical user base in the content creation process. This work describes the prototyping of such a co-creative process through several orthopedic educational topics. The design process of the content is described, along with the provision for facilitating a non-tech savvy expert towards the co-creative endeavor. Initial insights along with future steps for evaluation of this process are also discussed.

Keywords: Medical education · Technology enhanced learning · MUVE · OpenSim · Co-creation

1 Introduction

1.1 MUVEs in Medical Education

The advancement of computer gaming and particularly Massively Multiplayer Online Role Playing Games (MMORPGs) has prompted a fascinating twist, the Multi User Virtual Environment. A Multi User Virtual Environment (MUVE) has been characterized a synchronous, persistent network of people, represented as avatars, facilitated by networked computers [1]. The attributes of this definition likewise portray the favorable characteristics for instructive purposes. The synchronous networking of users

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flawlessly encourages cooperation between them in pursuit of a shared objective, being that objective either the annihilation of a beast in a game, or the treatment of a virtual patient in a healthcare education context. Moreover, the graphical delineation of the user in a human resemblance of her/his decision, certainly encourages the immersion of her in the virtual condition. This empowers the user to take an interest in the online episode with significant experiential impact [2].

Second Life is one of the most established multiuser virtual environments. In that capacity it is very developed in assets and dependability. It has spun off an entire open source 3D MUVE application server, specifically OpenSim [3] from which a lot of more contemporary MUVE "Grids" have been brought forth.

With respect to subjects experienced in SL healthcare instructive material, one can discover numerous and assorted parts of the therapeutic educational programs from its core curricula, e.g. anatomy [4], to specialty material like pediatric care [5], pneumonology [6], cardiopulmonary revival [7, 8], dentistry [9] and emergency topics [10]. Other endeavors incorporate such various themes as handicap healthcare [11], pharmacy training in communication abilities [12], or in the general aspects of their specialty [13]. It is fascinating to take note that the primary hurdle in every one of these undertakings has been recognized as the huge specialized overhead to develop the particular substance. In this challenge, the concept of co-creation offers an innovative solution.

1.2 Cocreative Knowledge Transfer

Cocreation is an idea that has developed in marketing and particularly in the zone of product design. There it has been initially named value co-creation as it was a procedure for characterizing an item's value offer through participatory techniques rather than the standard statistical surveying roads [14, 15]. In VCC, clients/users take a dynamic part and make value together with the key stakeholder (firm, creators) [14, 16]. Engagement, communication, self-reliance, and experience are perceived as the vital components of the joint formation of added value [17]. Be that as it may, VCC is superordinate to these components as it reaches out past the generation anchor to the utilization and value delivery chain [14, 18]. Further, however contemporary specialists [19] have listed upwards of 27 unique definitions, that can be arranged into one of two components of VCC that we term co-creation and Value in Use (ViU). Such depiction of theoretical concepts in VCC is bolstered in earlier literature about VCC as a combined impact of co-creation and buyer skills [18, 20, 21].

Cocreation connects with buyers/clients through their dynamic support in new item improvement [22, 23] as co-production. Co-production comprises of immediate or indirect "cooperating with clients" [24, 25] or interest in the product/service configuration process [26, 27]. Client investment may be in an assistive part at the outskirts of a company's procedures [26], or in a more core, dynamic part through the utilization of learning and sharing of data and expertise with the firm [28, 29]. Co-creation is additionally described by client association through demonstrations of shared trade, physical and mental activities, and access to common masteries [30]. All the more, for the most part, co-generation is an arrangement of actions completed by financial and social actors inside the value chain networks [31, 32]. It is executed through coordinated effort [33] and exchange [34, 35] to incorporate common assets into value generation [36]. As clients expend assets in the co-creation forms, it is viewed as both a helpful demonstration fulfillment, and an exploitative ploy of an expanding firm [37, 38]. Overwhelmingly, in co-creation, the locus of control of the procedure lives with the firm, which characterizes the nature and degree of co-production [39]. It, in any case, does not preclude the likelihood of clients being fully engaged with the co-production process [40, 41]. A few investigations feature value as mutualism, receptiveness, and non-hierarchical relations [29, 37] as a critical element of co-production. Thus literature review [15] exposes as one of the main factors of co-creation efficacy the sharing of knowledge. It is this exact sharing of knowledge that is tapped in the field of medical education for the co-creative effort. The target group for medical education content is the medical sector and this exact segment is also the one that has the expert knowledge that needs to be used for creation of medical education content creation. Given this incentive, it is the goal of this work was to prototype a co-creative workflow for exploratory self-directed learning in the widely used OpenSim MUVE. To achieve this we have used as pilot a sample of orthopedic topics for inclusion in the OpenSim co-created learning environment.

2 Methods; Supporting the Co-creation Process Through Sound Design Choices

2.1 Choice of Deployment Platform

The prototyping process started with the choice of the educational content deployment platform. OpenSim is a mature 3d MUVE that has all the desirable characteristics that facilitate the cocreative workflow. Its immediacy as an interactive space is desirable so that the user/creator can easily visualize how the content that she wishes to include, will be presented in the environment. Additionally, the ease of content creation was the key in the selection of the platform. Simple or even sophisticated content can be created only through graphical manipulation and without almost any coding. Finally, OpenSim provides enough content availability in the form of assets that can be used with little or no technical expertise. That allows for diverse and impactful content to be created by the non-technical user/creator.

2.2 Experiential Media Inclusion

Audio and video content was decided to be used in this prototype due to its impact in the learning process. A question was raised during the prototyping design of whether a non-expert would be able to create quality audiovisual content for use as educational content. This concern was alleviated, since the user herself successfully used the everyday recording capacities of her mobile phone and managed to produce appropriate quality videos for use in the environment. Furthermore, the incorporation of this content in OpenSim, is straightforward and does not require any technical knowledge. In that context the inclusion of video content was deemed not only impactful regarding the content, but also compatible with the capabilities of the user/creator that was engaged in the co-creative process.

2.3 Effective Narrative Interaction

To facilitate user engagement it was deemed useful to utilize interactive content. OpenSim utilizes a simple scripting language (LSL [42]) which is adequate for most simple interaction scripting. This language however uses standard coding provisions (loops, variables, conditionals) which were beyond the capabilities of the medical expert that was participating in the cocreation effort. To alleviate this roadblock, a technical expert discussed with the medical expert the necessary interactions. The simple interaction that was decided to be used was a series of posters that described a medical case. The user should be able to select through interactive buttons one of multiple choice responses about the treatment and then proceed to the next poster that provides feedback and offers further choices. To support this a spatial interaction through the shifting (forwards and backwards) of each poster was devised and a template script was created. This script was described to the user/creator and he was provided specific written instructions with examples on how to edit each instantiation of the template script in order to be able to create his own case flow. Additionally OpenSim can integrate image content without any technical needs from its user. With these provisions and context in place, the co-creating user was able to author her own medical case flow with no technical supervision.

2.4 Exploratory Immersive Spaces for Topical Engagement

An approach suggested by the expert user/co-creator was the inclusion of “Education Corners”. Each of these corners would immerse the visitor in one specific topic. This was achieved through large (wall sized) posters of photos and text in each corner. It is interesting to note that the user/co-creator of the content, once acquainted with the capacities of OpenSim was able to individually and without technical support to devise and put in place the layout of these corners.

2.5 Blended Narrative-Exploratory Learner Centric Approach

The overall goal for the learning experience was to create an environment that allowed the users to take initiative, explore an interactive educational space and learn at their own pace. Given the fact that both an interactive narrative and an exploratory exhibit-like space was feasible, the decision was made to create a blended space that would include both approaches. It must be emphasized that the key innovation of this work does not so much lie in the virtual environment or in the resources deployed. This work presents a method for innovatively incorporating mainstream resources and platforms for facilitating seamless co-creative methodologies in order to support rapid educational content development.

3 Results; Cocreative Educational Implementation

The design decisions above, have been implemented in the blended education space that was built in an available OpenSim Grid as a proof of application. This work followed a technically hands off process. First the user/co-creator, after participating in the design process above, was tutored in the use of OpenSim and the scripting template that was developed for the interactive part of this space. Then the user was left alone to develop that content according to his own specifications and was instructed to contact the technical team only if he was unable to proceed in any way. If that was to happen the technical problem would be alleviated by the technical team but no content addition would occur from this team as the objective was to create this space through a co-creative process.

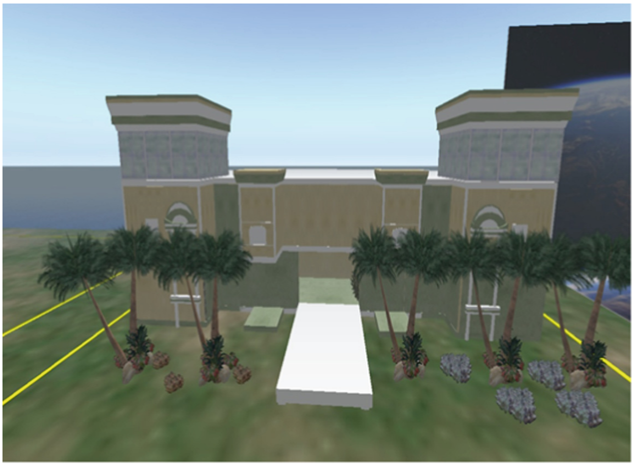

Fig. 1. The exterior of the educational space.

Training takes place in an pleasant space that triggers the imagination through its architecture Fig. 1. The students can explore and be informed on their own immersing themselves to the "educational corners" (Fig. 2). In each of these corners images from X-rays and photographs of patients for different orthopedic conditions are presented along with textbook excerpts for the learner to peruse. In the center of the space there is a small auditorium where 4 large viewscreens play educational videos (Fig. 3) for these same cases in order for the learners to summarize their knowledge after they have visited each corner. At the opposite to the entrance wall a series of panels have been scripted to present one of the orthopedic conditions as an interactive virtual scenario (Fig. 4). The user, after initializing the case through a button, is presented with the first panel narrating the initial history and context of the case. After that, the user can use the buttons that are besides each of the panels to select one of three choices for the current stage of the scenario. Each button leads to a different path for the scenario and the user needs to make four correct choices in total to deal with the orthopedic surgery case in an optimal way.

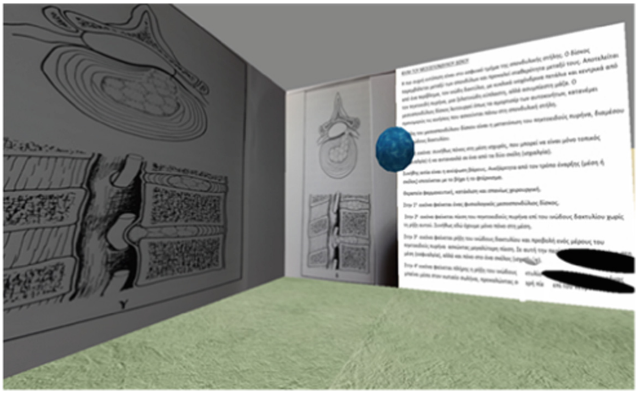

Fig. 2. An example of an "educational corner".

Fig. 3. The educational video area.

The learner is free to negotiate the content of the space at her own pace and in any order that she chooses. In the interactive case no score is presented but positive or negative feedback is provided by the narrative in the panels of the case which provides affective feedback to the learner regarding success or failure.

It must be noted that in that process a simple miscommunication regarding scripting, editing and saving has led to the loss of almost a day as the user/co-creator was unable to manage the content that he has created with the scripting template. This hurdle was alleviated by reverting the template to its correct form and further training the user/co-creator in the exact details that needed to be followed when using the scripting template.

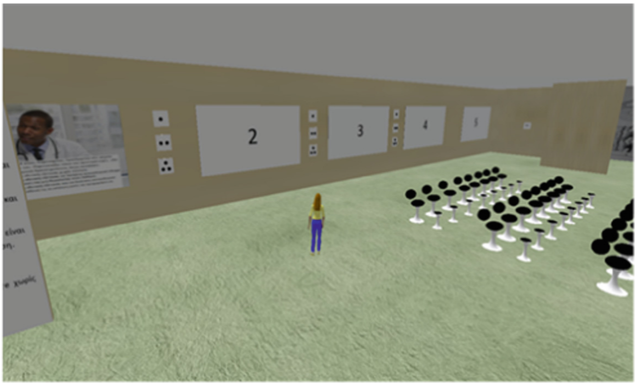

Fig. 4. The interactive scenario area.

After that the whole process was completed in a span of 3 days of part time work (15 h in total).

4 Discussion

In the medical education domain one of the core challenges in educational content generation is that of massive topical content. Since the 80 s, medical knowledge doubled almost every two years [8]. This turned educators to technology in order to cope with the volume and critical nature of this content [42]. The overarching goal of all such endeavors was ubiquitous access to clinical skill development tools [43]. This work describes the prototyping of a co-creative process for medical education content development in order to allow digital medical content creation to keep pace with the rapidly expanding knowledge in the medical field.

From this co-creative process a blended exploratory/interactive educational space for orthopedics was developed. This space was designed, as was demonstrated in this work, with focus on a balance between an ease of use approach and an educational efficacy requirement. Specifically the design of the space was based on existing assets and prior technical scaffolding before the expert got engaged. That way the expert could own the rest of the content creation process and be a true co-creative participant in the creative endeavor. The core sophistication for interaction was the simple scripting template that required only duplication and parametrization from the topical expert user/co-creator.

This process is not however without risks. Small errors in design and even small miscommunications can lead to a breakdown of this process as has occurred in this process. This kind of issues are core for enabling co-creation of medical content from medically expert but not tech-savvy users. Most of the content development platforms (e.g. Unity [44]) are powerful game development engines, while even gamified creative virtual environments require programming knowledge to facilitate content creation.

These issues are getting more and more alleviated as the generations shift from technology illiterate towards not only technology literate but technology natives [45–47]. This shift shifts the experts' demographic towards people who are familiar not only with the use of technology but also with base programming concepts (branching-looping etc.) and thus they can become more robust content co-creators. Furthermore most aspects of technology are moving towards a user-centric design paradigm [48] that has already dominated consumer technology products.

This work is a probing step in this direction for medical education content creation. This prototyped process is going to be evaluated further from more expert users/co-creators and specific conclusions are going to be extracted. Content created is going to be evaluated by medical students and specific guidelines for quality of content are going to be summarized. The overarching aim of this process is the transformation of the medical content creation from a technical, coding process to a co-creative, user-centric, intuitive workflow that most contemporary medical experts will be able to follow without technical guidance.

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