Tassos Anastasios Mikropoulos *Editor*

Research on e-Learning and ICT in Education

Technological, Pedagogical and Instructional Perspectives

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Introduction

Information and communication technologies (ICTs) have their unique characteristics and thus afford specific actions. ICTs have certain affordances, defined by Michaels as “goal-directed … actions permitted an animal by environmental objects, events, places, surfaces, people, and so forth.” Affordances “exist independent of being perceived” and “are specified by information and may be perceived” (2003). The affordances of ICTs are their characteristics to record, store, and process data and information. In general, the affordances of ICTs are their potentialities, i.e., (1) to represent information in multimodal, dynamic, and interactive ways and (2) to support synchronous or asynchronous communication. These affordances get specific forms in various ICTs configurations. Thus, the affordances of mobile devices include ubiquity and pervasiveness, geolocation, sensing, and finger control. The affordances of multiuser virtual environments (MUVEs) are multisensory intuitive and real-time interaction, immersion, presence, autonomy, natural semantics for the representation of objects and facts inside the virtual environments and worlds, users’ representation through avatars, first-person user point of view, first-order experiences, size in space and time, transduction, and reification (Mantziou, Papachristos, & Mikropoulos, 2018).

In the field of education, the unique features of ICTs “afford actions that may be used in teaching and learning and consequently lead to learning benefits” (Mantziou et al., 2018). Thus, the learning affordances of mobiles include creation, multichannel communication, collaboration and cooperation, experimentation, real-time/anytime/anywhere information, and content delivery. In the same vein, MUVEs’ learning affordances are free navigation, modeling and simulation, creation, multichannel communication, collaboration and cooperation, and content delivery. The potential of ICTs in teaching and learning is the perception and enactment of learning affordances of the environment by designing and implementing meaningful learning activities that can lead to learning outcomes (Dalgarno & Lee, 2012; Mantziou et al., 2018). These learning activities implement a series of instructional strategies that are based on certain didactic models and learning theories (Fig. 1).

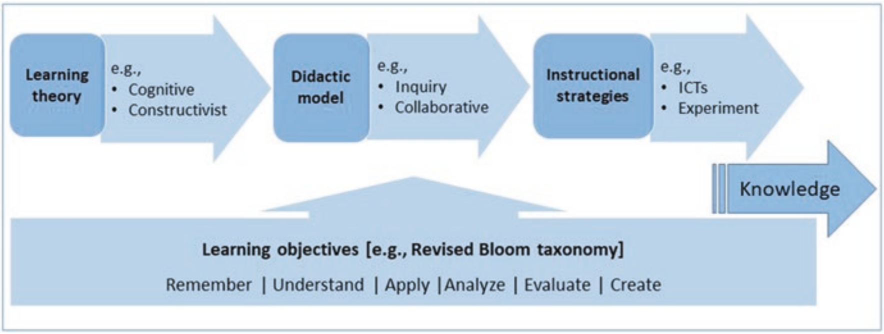

Fig. 1 Implementing meaningful learning activities with ICTs

Therefore, the introduction of ICTs in education has two sides, that of the technologies and the other of the pedagogical approach. There are different approaches to the pedagogical use of ICTs and in particular for each one of the different technologies. Nowadays, researchers propose theoretical approaches, develop ICTs tools, design e-Learning environments, conduct instructional interventions, and evaluate both the approaches and the tools.

This book reflects the above considerations and the current trends in ICTs. It comprises 23 chapters from researchers in Canada, Greece, Portugal, Norway, and Cyprus. Their work was presented at the 10th Pan-Hellenic and International Conference on ICTs in Education—HICICTE 2016, organized by the School of Education and the Department of Computer Science and Engineering at the University of Ioannina in Greece, in collaboration with the Hellenic Association of ICT in Education—HAICTE. Initially, the articles were positively peer-reviewed by at least two reviewers. The chapters of this volume are extended articles of the originals presented at the conference or were invited for this purpose and underwent an additional review process.

The 23 chapters constitute two main categories. The first category of the chapters concerns ICT approaches to the teaching and learning process, while the second one pertains to ICT interventions in the teaching process. The chapters relevant to the approaches of ICT in education and e-Learning concern (a) creativity and collaboration, (b) higher education, and (c) educational organization and professional development. The chapters regarding the interventions in the teaching process cover (a) digital educational games, (b) physics, computer science, and mathematics education, (c) educational robotics, and (d) vocational training.

Approaches to Education

The affordances of digital technologies, like mobiles, offer opportunities for collaborative learning environments. Their affordances, and especially that of interactivity, also give the chance for the development of creativity. Mercier points out the benefits of collaborative learning and emphasizes the affective aspects of co-learners. The author, following theoretical foundations and experimental research, supports that psychophysiological data may contribute to modeling cognitive and affective learning interactions of co-learners in a collaborative setting. Mercier also proposes that neuroscience methodologies could carry forward collaborative learning.

Daskolia, Kynigos, and Kolovou address creativity within the collaborative design of digital education resources. Their study focuses on the design of digital books for environmental and mathematics education. The authors emphasize the contribution of social aspects of creativity into a collaborative design and present supporting empirical data.

Nikolopoulou proposes the use of ICT tools for the development of creativity in a school setting. She grounds her proposal on a theoretical background and supports it by a small-scale empirical study with Greek high school students. ICTs are known to contribute to the development of creative educational activities. Thus, the dynamic and interactive character of their affordances seems to fit with the basic features of creativity.

ICTs are often used in higher education mainly for content delivery. In recent years, ICTs contribute as learning tools. Maia, Borges, Reis, Martins, and Barroso discuss the integration of ICTs in higher education and present the needs and expectations of professors at a Portuguese university in a pilot study. The authors' findings show that although the university professors are strongly interested in using ICTs in their teaching, their adoption is lower than is desirable.

Beyond the teaching needs, ICTs may also contribute to the evaluation process in a higher education institution, as the above authors present. Reis, Paredes, Borges, Rodrigues, and Barroso propose a software tool to support performance evaluation, a standard process in tertiary European education. A pilot empirical study on the use of the proposed tool shows promising data for the contribution of ICTs in the evaluation process.

Researchers in the field of ICTs in education and e-learning also study topics regarding administrative issues in school settings. Livieris, Drakopoulou, Mikropoulos, Tampakas, and Pintelas propose the use of educational data mining to predict students' performance in order for the education stakeholders to provide them with better educational support. The authors present an original and ensemble-based semi-supervised method. Experimental results reveal that the proposed method is effective for early progress prediction for students when compared to other semi-supervised learning methods.

Laschou, Kollias, and Karasavvidis study transformational leadership in schools and especially principals' views on the use of ICTs as tools to promote educational innovations. The results of their empirical study show that the views of transformational principals are different compared to the corresponding visions of the academic and research community. This indicates that the implementation of ICTs in education is a complicated and lengthy matter, as it is also supported by relevant studies in higher education.

Two chapters refer to teachers' professional development as far as it regards the use of digital tools. Hadjileontiadou, Dias, Diniz, and Hadjileontiadis explore the potential of digital concept mapping under self- and collaborative mode within emerging learning environments like intelligent LMSs. The authors propose a new approach to concept mapping creation by combining the LMS use with the collaborative construction of concept maps. These maps are of high quality, as it was supported by their empirical study with high school teachers participating in a professional development program.

Free and open-source software has been introduced in the teaching process since the 1990s, and Armakolas, Panagiotakopoulos, Karatrantou, and Viris explore high school teachers' attitudes toward its integration in the classroom. Greek teachers who were enrolled in a pedagogical training program expressed positive views toward its impact in achieving their learning objectives. According to the study's findings, teachers supported openness and thus the belief that knowledge is a public good. Moreover, the findings corroborate the need for teachers' further training on the pedagogical use of ICTs.

Interventions in the Teaching Process

Digital educational games are a promising tool in the learning process. Thus, this volume includes four relevant chapters, which refer to the design and evaluation of games in different disciplines and educational levels. Siakavaras, Papastergiou, and Comoutos review mobile games in computer science education and propose their own game for senior high school students. The review shows that, in general, designers do not use the unique affordances of mobile devices in their games.

Bratitsis presents the design of an online game on citizenship education, focusing on the European Union context. The author presents a game model based on constructivist and situated learning frameworks. This design aims at enhancing primary students' motivation and increasing learning outcomes. The content of the game is related to the rights and obligations of EU citizens, political, historical, and socioeconomic issues in EU, as well as cultural diversity in the region.

Koutromanos, Tzortzoglou, and Sofos present their augmented reality game for environmental education in primary education. The game model follows social constructivism and situated learning. The findings of their empirical study indicate that augmented reality is suitable for the design and the content of such games, despite some technical problems due to the environmental conditions.

Karsenti and Bugmann study the educational impact of a well-known commercial game on elementary school students. With a methodology that uses ten different types of data collection tools, the researchers indicated that their game contributes to the development of motivation and collaboration skills, computer programming learning, and the development of computer science competencies.

Science, computer science, and mathematics education is always a field of research interest because of the involved abstract concepts and the phenomena that cannot be studied in the educational environment. Since there is a huge repository of digital learning resources, mainly simulations, the research interest focuses on their evaluation based on specific models, usually inquiry-based learning. Olympiou and Zacharia investigate undergraduate students' actions while experimenting with a blended combination of physical and virtual manipulatives, as opposed to physical manipulatives. The results show that different means of experimentation evoke different procedures and actions during experimentation, findings that are of interest for both researchers and educators.

Taramopoulos and Psillos study the impact of virtual laboratories on secondary education students. Their empirical results show that teaching-by-inquiry electric circuits seem to support students' conceptual evolution while developing their experimental design and implementation skills.

Michaloudis, Molohidis, and Hatzikraniotis follow a similar approach to study inquiry-based simulations that promote scientific processing skills. The authors record high school students' actions, during their virtual experimentation in a horizontal throw. Their findings show that tracing the students' activity in inquiry-based studies may give insights into the design of the simulations.

Sandnes and Eika present another aspect of the use of ICTs in teaching inferential statistics to university students, identifying the lack of effective learning recourses and the lack of a proper pedagogical framework. The authors propose a simple pedagogical framework to improve the quality and validity of the statistical analyses carried out by the students.

Zaranis and Exarchakos investigate the contribution of ICTs in teaching and learning stereometry. The findings show significantly higher performance and satisfaction for the experimental group of civil engineering students in a context based on the Realistic Mathematics Education theory.

Markantonatos, Panagiotakopoulos, and Verykios evaluate a piece of software they developed to teach the concept of the variable. The core of their application is the representation of RAM memory as a one-column array. The results of their empirical study with high school students show that the digital activities increase students' motive and overall present with positive learning outcomes.

Educational robotics is a field of increasing interest in general and special education. The physical machine seems to diminish students' misconceptions and maintains their motive to learn. Karachristos, Nakos, Komis, and Misirli present the so-called e-ProBotLab, an early Programming Robots Laboratory for the construction and programming of robotic devices, suitable for the development of computational thinking. The authors introduce their prototype for the teaching of introductory concepts in mathematics, computer engineering, and programming.

Bugmann and Karsenti explore the use of the humanoid robot NAO in students with learning disabilities. The results of their study show that students 12–18 years old may increase their motivation to attend school, engage in learning tasks, and develop collaboration skills.

ICTs contribute to vocational training and there are the following two chapters in the volume reporting data in this field. Tsiopela and Jimoyiannis use their Pre-Vocational Skills Laboratory, a web-based learning environment aiming to enhance pre-vocational and employment skills of young adults with autism spectrum disorders. The results from five adolescents and their single-subject approach methodology indicate a continual improvement in students' performance.

Papachristos, Ntalakas, Vrellis, and Mikropoulos present an immersive stereoscopic virtual environment for training in culinary education. Their empirical study shows higher spatial presence for the high immersive version of the environment during the preparation of the recipes. Nevertheless, it seems that the lower immersion interface is more appropriate for such kind of virtual environments.

I hope this volume will contribute to the field of e-Learning and ICT in education and inspire the readers to do their own research. Moreover, I express my deep appreciation to all the contributors of this volume. I thank the Hellenic Association of ICT in Education—HAICTE, the authors, and the reviewers of the chapters. I also thank Joseph Quatela, Melissa James, Sara Yanny-Tillar, and Kiruthika Kumar from Springer US, as well as Katerina Kalyviotis for their generous assistance and excellent collaboration.

Tassos Anastasios Mikropoulos
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Contents

Chapter 1
The Feasibility and Interest of Monitoring the Cognitive and Affective States of Groups of Co-learners in Real Time as They Learn

Julien Mercier

Introduction

After decades of debate about whether or not neuroscience can contribute to education (Byrnes, 2012), and more recently about the requirements for productive research in educational neuroscience (Ansari, Coch, & Smedt, 2011), the time has come to use these recent prescriptions for the development of the field to devise new research agendas regarding specific educational problems for which educational neuroscience can provide solutions. It is suggested in this chapter that an educational neuroscience perspective on collaborative learning research may contribute answers to persistent questions related to how people learn in collaborative contexts and how learners' efforts can be optimized. Collaborative contexts in learning involve problem-solving tasks that have to be performed by more than one learner, typically two to six (Panadero & Järvelä, 2015). From a cognitive point of view, the enthusiasm regarding the positive impact of those contexts on learning is based on the notion that benefits of collaboration (more knowledge, more working memory, etc.) can outweigh the costs associated with the increased complexity of the situation (need for coordination, need for building a shared problem space, need for joint action, etc.).

Learning is attributable to events that occur at many levels and at different temporal grain sizes (Anderson, 2002). When collaborative contexts are implemented, this includes the level of the interaction between learners. With respect to this interaction, collaborative learning creates specific needs that the learners (and eventually sources of help) need to satisfy in order to optimize this interaction to foster learning outcomes. A new goal for collaborative learning is fostering preparedness for future learning (Gadgil & Nokes-Malach, 2012). Although many perspectives can

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contribute to the understanding of collaborative learning interactions (Clara & Mauri, 2010), a cognitive science perspective insists on how affect and cognition influence inter-individual processes in relationship with individual learning (Efklides, 2012; Kirschner & Erkens, 2013). In this view, under the notion of distributed cognition (Bratitsis & Demetriadis, 2013; Vasiliou, Ioannou, & Zaphiris, 2014), collaborative learning involves needs for joint action, joint understanding, and joint goals (Järvelä & Hadwin, 2013) that either have to be put in the service of learning (Blumen, Young, & Rajaram, 2014) or be satisfied without sacrificing learners' resources necessary for learning (Kirschner, Paas, & Kirschner, 2011). Research suggest that typically, groups perform better than the average individual, but individuals in groups perform worse than individuals working alone, probably because collaboration can overload cognitive capacities (Gadgil & Nokes-Malach, 2012; Kirschner et al., 2011). Gadgil and Nokes-Malach (2012) identified collaborative inhibition (either by disruption of retrieval strategies or production blocking) as one pitfall to avoid and error detection and correction as a team strength to capitalize on by appropriate pedagogical design to help individuals perform to their full potential during collaboration efforts.

Given the current emphasis on affect in learning (Immordino-Yang, 2011), we suggest that the notion of distributed cognition could be extended to distributed affect, especially as collaborative learning research begins examining affective aspects of computer-mediated collaborative learning (Colace, Casaburi, De Santo, & Greco, 2015; Jung, Kudo, & Choi, 2012; Robinson, 2013). These issues are increasingly studied in conjunction with new computer tools for computer-supported collaborative learning (CSCL) such as virtual reality (Bouras, Triglianos, & Tsiatsos, 2014; Goel, Johnson, Junglas, & Ives, 2013; Kirschner, Kreijns, & Fransen, 2014) as a means to foster social presence (Kirschner & Erkens, 2013; Mazzoni, 2014; Remesal & Colomina, 2013) and flow (Csíkszentmihályi, 1998; Goel et al., 2013; Van Schaik, Martin, & Vallance, 2012). The long tradition of scaffolding the interaction through scripts continues in current research (Bouyias & Demetriadis, 2012; Fisher, Kollar, Stegman, & Wecker, 2013; Foutsitzis & Demetriadis, 2013; Karakostas & Demetriadis, 2014; Noroozi, Biermans, Weinberger, Mulder, & Chizari, 2013a, 2013b; Papadopoulos, Demetriadis, & Weinbergert, 2013; Popov, Biemans, Brinkman, Kuznetsov, & Mulder, 2013, 2014; Popov, Noroozi, et al., 2014; Sobreira & Tchnikine, 2012) complemented by novel strategies such as providing diagnostic information to learners using interaction analysis (Fessakis, Dimitracopoulou, & Palaiodimos, 2013) or learning analytics (Haythornwaite, de Laat, & Dawson, 2013; Lu & Law, 2012; Martinez-Maldonado, Dimitriadis, Martinez-Monés, Kay, & Yacef, 2014; Palomo-Duarte, Dodero, Medina-Bulo, Rodríguez-Posada, & Ruiz-Rube, 2014). Overall, most of the benefits and pitfalls of collaborative learning can be related to how learners function moment by moment as the collaborative learning activity unfolds, sometimes over long periods.

Although some evidence has been provided with respect to cognitive load (Kirschner et al., 2011), most of the empirical work aiming at optimizing collaborative learning contexts on a moment-by-moment basis remains to be undertaken (Kapur, 2011; Lajoie et al., 2015; Wang, Duh, Li, Lin, & Tsai, 2014). It is plausible that how things unfold in sequence determines drastically the outcomes of collaborative learning efforts, and this perspective is potentially more informative than a focus on prevalence (how much of a given thing happend, irrespective of order). It should contribute to disambiguating perplexing results. For example, in a robust study that does not consider temporal information, Janssen, Erksen, Kirschner, and Kanselaar (2012) showed that discussion of information and regulation of task-related activities was not related to group performance. They also report that regulation of social activities positively affected group performance, whereas social interaction negatively affected group performance. Most of research on co-regulation and shared regulation is based on process data (Panadero & Järvelä, 2015), although the sequential nature of the process has rarely been examined (Kapur, 2011). For example, Khosa and Volet (2014) provide a coding scheme that is readily amenable to sequential analysis.

Regulation, representing the power an individual has on the limits of his cognitive abilities (universal or idiosyncratic), can be seen as the phenomenon of choice for studying the agency of the learners in a collaborative learning situation (Järvelä et al., 2015). Challenges are many and include needs for both conceptual and methodological innovations. Conceptual developments may take the form of cognitive models of the cognitive task of collaboration (possibly using the notion of cognitive architecture extended to multi-agent functioning (Clark, 2013a, 2013b; Sun, 2006) as presented in an upcoming section. Methodological advances may relate to the integration of new sources of data to existing methodology in the field, as suggested later in this chapter. From the perspective of the learner, the long history of research on metacognition places learning as the overarching goal that is mediated by contextual factors (internal and external) affecting the learner, but the ways to reach and maintain this learning-driven state are largely unknown in both individual (Azevedo, Moos, Johnson, & Chauncey, 2010) and group learning contexts (Järvelä & Hadwin, 2013).

By building on and bridging currently isolated work on monitoring and regulation of cognition and emotions from a behavioral perspective and a psychophysiological perspective, the approach to the study of collaborative learning presented in this chapter can provide a window into "missed opportunities for learning" that result from the joint suboptimal monitoring and regulation by conceptualizing these two processes synchronously in a group of students. The resulting view borrows from diverse disciplines including education, educational psychology, cognitive psychology, cognitive neuroscience, social neuroscience and work neuroergonomics.

In order to make the case that collaborative learning research can benefit from the integration of neuroscientific data, some of the most important issues the field currently faces are briefly discussed next. Afterward, a model of the cognitive challenges associated with monitoring and regulation in collaborative learning is presented to ground our proposition that co-learners would be able to regulate the interaction in significantly more productive ways if they were provided more information to monitor, and specifically information that is difficult to obtain in natural situations and which could be acquired through psychophysiological methods. In order to show how psychophysiological methods can be used in light of the current state of the research, this model is supplemented by the identification of specific sources of pertinent information. The concluding section presents some expected outcomes of this approach.

Regulating a Collaborative Learning Interaction: Self-regulation, Co-regulation, and Shared Regulation

An agent in collaborative learning situations, either the students or a computer tool, monitors and regulates aspects of task performance as well as the interaction between co-learners (Järvelä et al., 2015; Saab, 2012). Aspects of task performance include both affective and cognitive dispositions. Aspects of the interaction comprise individual level, the dyadic level, and the group level (Saab, 2012). This regulation of learning is advocated as the essential skill in collaborative learning (Järvelä & Hadwin, 2013) and thus deemed to be insufficiently researched regarding its multifaceted impact on learners as well as how to foster it through pedagogical design (Järvelä et al., 2015; Saab, 2012). Monitoring refers to the capacity of an individual to detect pertinent cues as they occur as ongoing processes unfold (Koriat, 2012), which in our case refer to cognitive and affective states in oneself or in the other individuals. According to Efklides (2012), correct monitoring is a prerequisite for adequate regulation, whereas regulation is the actions taken by the individual in response to those cues (De Bruin, 2012). Therefore, improving the actions of individuals in a learning situation, both the tutor and the tutee, largely lies in fostering their capacity to monitor the situation completely and accurately (knowing what is going on) and developing adequate responses to those cues (knowing what to do to improve the situation). While most theories postulate that monitoring is followed by regulation, Koriat (2012) introduces the possibility that regulation can occur without monitoring. Most of the previous research has focused on the prevalence of aspects of cooperation in learning and their relation with learning outcomes (Kapur, 2011), whereas the present context puts a particular emphasis on learning processes as they unfold and are modulated through the interaction, in the manner of Järvelä et al. (2015).

The notion of metamemory (see De Bruin, 2012), emanating from a relatively unrelated context of rote learning, provides insights about the nature of regulation by articulating its two key processes, monitoring and regulation, on the basis of the distinction between the object level and the metalevel. The object level is constituted of specific cognitions constituting the input for monitoring. The metalevel is where monitoring occurs and refers to the metacognitive thoughts and feelings about cognitions. Monitoring is the input for regulation, which occurs at the object level. Indeed, the outcome of monitoring informs the object level on how to regulate, that is, how to respond to the collaborative learning situation or to adapt behavior. According to De Bruin (2012, p. 247), "Improving monitoring accuracy therefore largely lies in improving the cues that students use when providing judgements of learning." We suggest that this endeavor could benefit from a conceptualization of monitoring as a reasoning process, in which the preferable way to diagnose the learning process is through induction. Improvement in learners' regulation could benefit from a conceptualization as problem-solving, in terms of highly contextualized if-then rules that can either be postulated and tested or induced from empirical observations. Self-regulation, co-regulation, and shared regulation are allegedly present in collaborative learning (Panadero & Järvelä, 2015).

A broad distinction between the three kinds of regulation is that self-regulation concerns an individual learner, whereas co-regulation is an unbalanced regulation of learning in which one or more group members regulate other member's activity, and socially shared regulation of learning (SSRL) is a more balanced approach to collaborative learning in which the group members jointly regulate their shared activity (Panadero & Järvelä, 2015). Self-regulation, co-regulation, and shared regulation operate jointly in collaborative learning (Järvelä & Hadwin, 2013; Panadero & Järvelä, 2015). According to these authors, self-regulation, in the context of collaborative learning, is the process by which a learner adjusts his own cognitive and affective contribution toward the group task. Self-regulation is a necessary but not sufficient condition for productive collaborative learning. Self-regulation can be present without the other types of regulation. Co-regulation occurs when the regulation of an individual is influenced by and with co-learners. Co-regulation is based on a mutual awareness of co-learners. The importance of this process is based on the benefits of peer support in learning interactions (Järvelä et al., 2015).

Shared regulation involves task perceptions and goals jointly constructed by co-learners (Järvelä & Hadwin, 2013). The empirical articles reviewed by Panadero and Järvelä (2015) characterized SSRL as the joint regulation of cognition, metacognition, motivation, emotion, and behavior. More precisely, "Socially shared regulation of learning involves the construction and maintenance of interdependent or collectively shared regulatory processes" (Järvelä & Hadwin, 2013, p. 28). Co-learners can jointly regulate their cognitive and affective dispositions (Järvelä & Hadwin, 2013). According to Panadero and Järvelä (2015, p. 4), "The most salient features of socially shared regulation of learning that have been identified are in terms of shared regulatory activities: (a) joint cognitive and metacognitive regulatory strategies (e.g., planning) and (b) group motivational efforts and emotion regulation." Thus, in their review of all existing studies, Panadero and Järvelä (2015) show a relationship between higher levels of socially shared regulation of learning and group performance and learning.

In this context, regulation of a student's own learning is notoriously suboptimal (Efklides, 2012), and this can be due either to inaccurate monitoring or inadequate control processes (Dunlosky & Rawson, 2012). Similarly, a learner's regulation of a collaborative learning interaction can be qualified and explained the same way (Järvelä & Hadwin, 2013; Kirschner et al., 2014; Lee, O'Donnell, & Rogat, 2015). Iiskala, Vauras, Lehtinen, and Salonen (2011) hypothesized that individuals detect and use metacognitive indicators in others in order to regulate their or the others' behavior in a social or collaborative context. Importantly, studies have shown that monitoring accuracy can be improved by corrective feedback (Efklides, 2012). The question then is how to provide co-learners with this corrective feedback.

Elements of the answer to this question can be obtained by focusing on information processing and communication. The protagonists in a learning interaction function on the basis of rarefied information: the limited bandwidth of conversation conveys only part of the information concerning individuals' cognition and emotions (Stevens, Galloway, Wang, & Berka, 2012), a situation even worse in the context of CSCL because the conversation is incompletely mediated by computer tools (Lee et al., 2015). As a result, the learning interaction may not be always optimized for learning. In this regard, Järvelä et al. (2015) call for the implementation of three design principles for supporting regulation in collaborative learning: (1) increasing learner awareness of their own and others' learning processes, (2) supporting externalization of one's own and others' learning process and helping to share and interact, and (3) prompting acquisition and activation of regulatory processes.

An important additional source of information in this context would concern phenomena that occur either outside conscious awareness or that cannot (always) be made explicit in real time during the course of the collaborative learning interaction because of the limited bandwidth of communication. The inclusion of psychophysiological data in relationship with behavioral data can provide at least part of the missing information. The challenge consists of identifying the critical concepts and to integrate them both conceptually and methodologically in collaborative learning research.

As a response to the call by Volet, Vauras, and Salonen (2009) for new methodologies in the study of self- and co-regulation including the use of psychophysiological measures, and taking into account the cognitive and affective aspects of regulation (Efklides, 2012), this section suggests some of those concepts, pertaining to (1) the cognitive state of the learner, including metacognitive aspects and aspects that are out of reach of metacognitive monitoring, (2) the emotional state of the learner, and (3) aspects of the interaction that may occur faster and beyond conversation.

Toward Multilevel Temporal Causality in the Modeling of Learning Interactions

The questions of what is learning and how to foster this process in a collaborative learning situation can only be understood completely using a multilayered view of human behavior, which postulates functional relations between brain activity, individual affective and cognitive functioning, as well as social interactions (Anderson, 2002). Our suggested general model based on a multi-agent cognitive architecture is summarized in the next section. This model may contribute to briefly subsume important aspects of current research on collaborative learning and performance, as well as on computer-based learning tools.

A specification of a multilevel view of cognition is necessary for the objective of educational neuroscience. The idea per se is not new (Newell, 1990) and neither it is for cognitive neuroscience (van Hemmen & Sejnowski, 2006) and education

(Anderson, 2002) and has been expanded over time to include social aspects (Sun, 2006). From a cognitive science perspective, human cognition is widely understood as an information-processing system constituted of many superimposed and interdependent levels (Anderson, 2002; Newell, 1990; Sun, 2006). Some of those levels are commonly distinguished on the basis of their implementation, that is, qualitative differences in the system by which the information is manipulated. The present work capitalizes only on the most dramatic qualitative shifts in implementation (Sun, 2006).

For the purpose of this chapter, the architecture is represented in terms of three levels corresponding to (intraindividual) psychophysiological functioning (the realm of cognitive neuroscience), intraindividual cognitive functioning (the terrain of cognitive psychology), and inter-individual cognitive functioning (the object of educational psychology). Interestingly, the time scale of learning is not manifest in this architecture.

If we contend that learning occurs in the brain, then the upper bound can be fixed to the rational band, corresponding to events occurring over hours. Cumulative effects of events in this rational band can produce an expert, with expertise in a domain requiring over 10,000 h of deliberate practice according to Ericsson, Krampe, and Tesch-Romer (1993). According to a neuroscientific definition of learning (Anderson, 2002), the lower bound of learning can be fixed at the time scale of hundredths or thousandths of seconds. It can be suggested that it will be the role of educational neuroscience to uncover which aspects of learning occur at each time scale in this architecture and to test within-level and between-level causal claims pertaining to those aspects of learning.

Within this framework, collaborative learning can be examined from the perspective of within-level processes associated with a specific level or alternatively from the perspective of between-level processes, as advocated in this work. One of the main problems to be addressed is the relative indeterminacy in the interpretation of states within a given level. As a general principle, it is argued that the indeterminacy of a given level can be decreased by considering adjacent levels. Higher levels provide context for a given observation, whereas lower levels provide the component elements of the target level. For example, conversation provides context for an increase in a psychophysiological measure of arousal, and, conversely, cumulative cognitive load inferred from continuous measures of brain activity (Antonenko, Paas, Garbner, & van Gog, 2010) can complement a learner's assertion at some point in the interaction that they need a break.

Indeed, each level has its own rules, principles, and constraints (Newell, 1990). For example, the social level operates on the basis of social conventions manifest in conversation; the goal-directed behavior of the intraindividual cognitive level functions within the constraints of working memory and attention, and the psychophysiological level bound to the constraints of neural networks. However, a level also functions in response to bidirectional relationships with the adjacent levels. In this light, it can be said that bottom-up influences include a time or implementation dependency principle, in which higher-level, more complex processes are slower. Conversely, top-down influences include an agency principle, according to which social and cognitive demands drive, respectively, the intraindividual cognitive and psychophysiological processes. This framework formalizes how brains, individuals, and groups (including a tutor-tutee dyad) operate and can be used to make predictions regarding how events pertaining to one entity may affect other events at the same or different level(s). This is crucial in studying how people learn in terms of complex trajectories of events and states, and this is why research programs in educational neuroscience can be highly pertinent to educational practice and policy by studying inter-level influences. The consideration of higher levels in the architecture amounts to conducting studies in educationally significant contexts of learning. In light of this, the brain-mind-behavior model underlying cognitive neuroscience may need to include a social dimension (Howard-Jones, 2011; Koike, Tanabe, & Sadato, 2015).

A study in educational neuroscience has to include data associated with many levels in the cognitive architecture, including at least psychophysiological and behavioral data (Coltheart & McArthur, 2012). Generally, levels-of-analysis issues arise when we attempt to bring findings and methods together that deal with phenomena of different scale and scope—spatially, temporally, or in terms of complexity (Stein & Fischer, 2011). It will not be easy, but the field needs to study directly how top-down modulation by means of designer learning environments (Clark, 2013a, 2013b) actually occurs. Although this is extremely difficult to study, it is critical, as education essentially manipulates top-down effects on learning (Goswami, 2011). It should be noted that in our view, it is not necessary from a practical perspective to study all levels intervening between the level representing educationally relevant processes and changes and a level at which critical events for learning occur. When it is not the case, the connection between those targeted levels should be explained by relevant theory.

This emphasis on sequences of events or states has permeated recent research on intelligent tutoring systems (ITS), especially in conjunction with systems incorporating natural language capabilities. For example, Forbes-Riley, Rotaru, and Litman (2008) use diagrams (pairs of antecedent-consequent events) in the context of a speech-enabled ITS to show that affect is a strong predictor of learning, particularly in specific discourse structure contexts. Curilem, Barbosa, and de Azevedo (2007) suggest a generic formalism for ITS development that draws upon state-transition diagrams. Stamper, Barnes, and Croy (2011) used machine learning to elaborate hints to be incorporated in an ITS. Their approach illustrates the value of a sequential approach (in this case Markov decision processes) in the contextualization of help messages within a learning domain. Moreover, machine learning has also been applied to the study of human tutoring. Boyer et al. (2011) use machine learning techniques (hidden Markov modeling) to establish hidden properties of tutorial dialogue. This translates into a series of hidden dialogue states that the authors interpret as the tutor and tutee collaborative intentions that can be used to select tutor moves according to contextual demands. The recent research reviewed here illustrates the potential of a focus on sequence of events in the design of computer-based interactive learning environments.

The value of a sequential approach is that a focus on sequences of events can help characterize and detect both successful and missed learning opportunities during a learning interaction. It can also be instrumental in formulating prescriptions in choosing the most effective contextualized moves in collaborative learning setting, a question still mainly unresolved (Boyer et al., 2011). According to these authors, the concept of state is informative for tutoring research in that it implies a degree of memory or adaptation to the actual situation that can be both generative in designing tutoring systems and developing tutoring skills as well as descriptive in explaining the effectiveness of specific characteristics of tutorial interaction. Since collaborative learning can be seen as another setting of co-regulation, it can be suggested that the value of a sequential approach as articulated by Boyer et al. (2011) can be extended to the study of collaborative learning.

Given the propensity of human cognition to function on the basis of associations between conditions and actions (if-then rules) (Anderson & Lebiere, 1998), it appears clear that this approach should be fully extended to the study of collaborative learning. Indeed, humans have a potential for adaptation and development that machines do not have, so continuities and discontinuities in sequences of events have to be empirically detected and conceptually interpreted by considering traces of learning over extended periods of time. In addition, human intentions may not be ideally represented as relatively simple pairs of antecedent-consequent events, and may need to be understood differently. Human intentions may take the form of longer sequences of events (trigrams, etc.) and/or the form of lagged events, in which a critical event serving as a cause may be separated from its consequent by a certain number of states (Bakeman & Quera, 2011; Kapur, 2011; Reimann, 2009). The automata theory and the dynamic systems theory provide the foundations for this sequential approach.

Adding a Neuroscience Perspective in the Modeling of Learning Interactions in Collaborative Learning

This section argues that many variables and metrics studied in cognitive and affective neuroscience are determinant for learning and have the potential to move collaborative learning research forward by complementing the information naturally available from behavioral data in the modeling of learning interactions. Educational neuroscience is instrumental in conceptualizing and measuring emotions and thinking concomitantly over time, as affect and cognition unfold in natural learning situations (Immordino-Yang, 2011; Patten, 2011). Moreover, neuroscience can help in the study of how people interpret the actions and intentions of others (Sedda, Manfredi, Bottini, Cristani, & Murino, 2012), an aspect critical for collaborative learning. Many of these variables and metrics can be measured dynamically in the context of a collaborative learning interaction, that is, in conjunction with behavioral data typical of the field (conversation, gestures, interaction with computer-based learning tools, performance trace and products, etc.). Measurement equipment such as eye tracking, electroencephalography (EEG), galvanic skin conductance, electrocardiography, blood pressure, and respiration sensors are allowing empirical experiments with relatively high ecological validity. Recent developments in these technologies make available integrated wireless systems that facilitate synchronized and less intrusive data collection which do not disrupt the natural interaction. Many constructs are measured through one or more of these indicators. Some constructs pertinent for the study of learning are presented next and include attention, cognitive load, emotions, motivation, interest, and engagement. In the following, we show through a review of current literature how two lines of research can converge and eventually contribute to the study of collaborative learning. One body of work concerns the measurement of individuals in interaction in situations and with respect to elements not necessarily related to educational contexts, while the other is related to the measurement of important constructs for the study of collaborative learning, not necessarily measured so far in interactive settings.

Psychophysiological Measurement During Collaborative Learning Interactions

An emerging body of empirical work, scattered over many fields, indicates that inter-individual processes such as cooperation are beginning to be studied in cognitive neuroscience, demonstrating that in principle, aspects of affect and cognition in collaborative learning can be monitored in authentic contexts. Psychophysiological studies hinging on cognitive and affective modeling involve collecting behavioral and psychophysiological data for the two individuals in interaction, in the interactive approach (Konvalinka & Roepstorff, 2012; Mattout, 2012). The creation of this model involves the amalgam of existing theories describing (1) the social processes of learning situations, (2) cognitive and affective individual functioning, and (3) the psychophysiological substrates of behavior and learning. According to Di Paolo and De Jaegher (2012), interpersonal coordination can happen at the level of bodily movement; posture; physiological variables, such as heart rates and breathing patterns; autonomic responses such as galvanic skin conductance; and patterns of brain activity. Interpersonal coordination happens spontaneously and sometimes even against the individual intention not to coordinate. Coordination may involve the performance of similar movements (rocking chairs, finger tapping) or the timing of more complex actions, not necessarily similar to each other. Interpersonal coordination is also reflected in gaze patterns (Schneider & Pea, 2013, 2014). Each type of measure that can contribute to the study of collaborative learning is discussed next.

Brain Imaging

Brain imaging techniques measure structural and functional aspects of the brain. That is, the size of the brain and its various structures can be precisely established. Technically, brain imaging techniques such as near-infrared spectroscopy (NIRS), functional magnetic resonance imaging (fMRI), and high-density electroencephalography (EEG) can be coupled and used to record brain activity concurrently in more than one person. This setting is gaining in popularity especially with EEG, because of its appropriateness in naturalistic settings (Burgess, 2013), but first trials date back to the 1960s. Such settings are currently identified in the literature as dual EEG or hyperscanning (Koike et al., 2015). Some of this work involves extending the fMRI hyperscan technique to continuous dual-EEG recordings (Astolfi, Cincotti, et al., 2010; Astolfi, Toppi, et al., 2010). To date, although the dyads are the norm, the technique has been used with groups of four and in at least one case up to six individuals. Although this research is relatively recent, it is flourishing, and its potential is noteworthy, especially as its focus transitions from imitation to the study of complementary roles in increasingly complex social interactions. Activities range from finger tapping (Konvalinka et al., 2014), playing music in duets and quartets (Babiloni et al., 2011; Sanger, Muller, & Lindenberger, 2012; Wing, Endo, Bradbury, & Vorberg, 2014), playing card games (Babiloni et al., 2007) to even talking, drinking, and eating during a social event (Gevins, Chan, & Sam-Vargas, 2012). The contexts in which dual-EEG measurements were achieved and analyzed productively indicate that these methodological tactics can be applied in relatively authentic settings of collaborative learning involving movements and even speech. Even with significant data loss in the most demanding, most ecologically valid settings, the information represents major gains in tracing learning processes.

More specifically, many studies show that the complementarity of behaviors is related to synchronized inter-individual patterns of brain activity in which the EEG of each individual represents a different cognitive activity required for joint performance. This has been shown in finger tapping in leader/follower dynamics (Konvalinka et al., 2014), but also in the more complex setting of synchronized artistic activity such as guitar duets (Sanger et al., 2012) and collaboration/competition in dyads during four-player card games (Astolfi, Cincotti, et al., 2010). Konvalinka et al. (2014) showed that individuals within dyads become more mutually adaptive over time. Major breakthroughs in the study of teamwork in large groups were achieved by Stevens et al. (2012). Using the EEG measurement of subteams of six individuals who were part of teams of 12 representing the crew of a submarine, they showed that task engagement shifted among these individuals as a response to changes in task demands (submarine piloting and navigation) on a second-by-second basis. With respect to measurement using EEG in authentic contexts, one quite ambitious successful example is reported by Gevins et al. (2012). These authors measured the effect of alcohol on brain functions in a group of 10 people during a cocktail party, and 60% of the EEG data was analyzable despite natural movements, talking, eating, and drinking. The implications for the study of collaborative learning are that this information cannot be obtained using behavioral data.

Notably, Koike et al. (2015) reviewed empirical studies using EEG and supporting the multi-agent architecture presented above and on the basis of this theory convincingly reaffirmed the potential of brain imaging, especially EEG, in the study of social interactions in learning. They also demonstrate that applying current analysis strategies to multi-brain data as a whole should lead to neuromarkers of the learning process in social contexts. Eckstein et al. (2012, p. 107) summarize the potential and challenges of this approach: "Other applications of multi-brain computing include higher performance for cortically coupled computer vision systems and assessments of collective cognitive and emotional states to continuous dynamic stimuli and/or environments. The technology would be limited by the potentially extractable neural correlates of internal cognitive variables through EEG; yet the multi-brain computing framework is potentially applicable to other better measures of neural activity that might be developed in the future."

Eye-Tracking

Eye-tracking measures where a person is looking on a computer display using a special monitor or in the natural field of view using eye-tracking googles. Early, very intrusive techniques such as special contact lenses pioneered in reading research date back to 100 years (Poole & Ball, 2005). Lai et al. (2013) characterize eye-tracking data using two main dimensions: types of eye movement (fixation, saccade, mixed (e.g., scanpaths)) and scales of measurement (temporal, spatial, frequency count). The use of eye-tracking methodology by educational researchers has only recently begun and intensified in the past 5 years (Lai et al., 2013). Temporal measures may answer the "when" and "how long" questions, whereas spatial measures may answer the "where" and "how" questions in relation to cognitive processing. The interpretation of these measures is highly dependent on the context. Using various scales of measurement, fixations have been related to interest and uncertainty in recognizing a target item, and saccades have been related to processing difficulty and scanpaths to search of information. A few very recent studies show that eye-tracking methodology can be extended to the study of dyads, both in terms of synchronous data acquisition and in terms of analysis (see Belenky, Ringenber, Olsen, Aleven, & Rummel, 2014; Schneider & Pea, 2014). Dual eye tracking has been used to measure how gaze from interacting individuals are interacting, typically in the form of cross-recurrence gaze plot and networks which show the quality of collaboration, but this information has not yet been fully translated into theoretical constructs, with the early exception of joint attention. Schneider and Pea (2014) contributed significant advances in the analysis of dual eye-tracking data in suggesting to combine temporal as well as spatial information, traditionally considered in isolation. In another study, they also showed that when co-learners see in real time where the teammate is looking in a shared computer-based learning environment, they achieve a higher quality of collaboration and higher learning gains (Schneider & Pea, 2013).

Psychophysiological Indexes

Psychophysiological variables, such as heart rate, breathing patterns, and galvanic skin conductance, have not been studied extensively in dual or multi-individual measurement contexts, but pioneering work shows the potential of this approach. Synchronous arousal as measured by heart rate has been demonstrated in large groups and related to empathy (Konvalinka et al., 2011). In the context of a choir, inter-individual synchronization of cardiac and respiratory patterns reflects action coordination within a group (Müller & Lindenberger, 2011). Moreover, these authors have shown causal effects of the conductor on this inter-individual synchronization between singers.

Importantly, these results also show globally that the EEG and other psychophysiological measures in group contexts complement conventional communication metrics and are affected by aspects of collaborative performance. In the context of collaborative learning, these measures would be indicative of the effect of one protagonist on the cognitive and affective state of the other beyond what is manifest in the conversation, both in terms of time scale and content, and even beyond what is amenable to conscious verbalization, that is, outside the realm of metacognition. However, assessing the significance of this complementary information fosters the need for theoretical developments linking psychophysiological functioning with affect and cognition at the intra- and inter-individual levels (such as Clark, 2013a, 2013b) as well as methodological innovations.

At the inter-individual level, Di Paolo and De Jaegher (2012, p. 1) suggest that "the brain is potentially less involved in reconstructing or computing the 'mental state' of others based on social stimuli and more involved in participating in a dynamical process outside its full control, thus inviting explanatory strategies in terms of dynamical concepts such as synergies, coordination, phase attraction, (meta)stability, structural stability, transients, and stationarity, etc." These concepts have been already proven to be useful in behavioral approaches in the study of systems dynamics (Bakeman & Quera, 2011). Such a view highlights the potential of grounding the interpretation of psychophysiological data in episodic properties of interactions discussed previously. In other words, this view helps in linking psychophysiological sources of information with characteristics and states representing how collaborative learning interactions unfold naturally, beyond the study of either individual or contextual influences on learning.

Altogether, these studies show how it is possible to collect psychophysiological information in situations comparable in terms of technical challenges with collaborative learning settings. The remaining question, examined next, is what information can be derived from these measures in terms of constructs that would contribute to current issues in collaborative learning.

Psychophysiological Measurement Related to Monitoring and Regulation of Affective and Cognitive Aspects of Learning Interactions

While the previous section aimed to discuss the measurement of inter-individual processes, this section shows that psychophysiological measures of affective and cognitive processes in individuals in isolation can be the basis for studies of collaborative learning settings. One way is simply to replicate single-individual approaches in interactive settings to explore how individual processes co-occur and covary and mutually influence each other in inter-individual settings. Another way is to extend analytical approaches so that emergent inter-individual properties of the interaction, which cannot exist without interaction, can be investigated.

Brain Imaging

Among the educational constructs measured using EEG, cognitive load is one of the most promising to date because of its pervasiveness in educational psychology research (Antonenko et al., 2010) and history of methodological developments (Berka et al., 2004; Poythress et al., 2006). Indexes of engagement have also been developed (Freeman, Mikulka, Scerbo, & Scott, 2004; Pope, Bogart, & Bartolome, 1996; Poythress et al., 2006) and are currently applied to individual learning contexts (Charland et al., 2015). Distraction has also been measured in educational contexts using this approach (Stevens, Galloway, & Berka, 2007). Stikic et al. (2014) used continuous EEG to classify emotions as positive and negative. Their results suggest that a probabilistic estimation of positive and negative affect can be derived reliably for 2-min episodes (corresponding to the structure of the story) within a 19-min narrative story. Joint attention was reflected in dual-EEG patterns and may complement the eye-tracking methodology presented next (Lachat, Hugueville, Lemaréchal, Conty, & George, 2012).

Eye Tracking

Dual eye tracking has been recently used to investigate individual attention and joint attention in learning (Belenky et al., 2014; Schneider & Pea, 2014). Schneider and Pea (2014) emphasize that an analysis at the dyad level, in contrast to a focus on both individuals in a dyad, is much more informative in exploring interactive processes such as joint attention. Schneider and Pea (2014) have predicted aspects of the quality of students' collaboration using dual eye-tracking methodology. Joint attention was related to the quality of collaboration. They also conclude: "In summary, there are multiple studies showing that computing a measure of joint attention is an interesting proxy for evaluating the quality of social interaction" (p. 373). This suggests that merely counting the number of times subjects share the same attentional focus provides a good approximation for the quality of their collaboration. One can imagine that devoting so much attention and effort to one place reflects subjects' engagement toward the problem at hand. Belenky et al. (2014), in a study of joint attention similar in methodology to the study of Schneider and Pea (2014), found that joint attention was related to gains in conceptual knowledge in learning basic fraction equivalence. The authors conclude that joint attention may be crucial in learning from procedural problems and not important in learning from conceptual problems. In their review of existing eye-tracking studies related to learning, Lai et al. (2013) identified seven themes: patterns of information processing, effects of instructional strategies, re-examination of existing theories such as conceptual development and perception, individual differences, effects of learning strategies, social and cultural effects, and, finally, decision-making patterns.

Psychophysiological Indexes

Skin conductance is a correlate of affective states that can be useful in learning contexts (Fulmer & Frijters, 2009). For example, high arousal may be associated with reaching an insight in understanding new content (Schneider & Pea, 2014). Using false biofeedback, Strain, Azevedo, and D'Mello (2013) showed that perceived increased arousal with a positive valence was associated with more confident metacognitive judgements and increased performance in answering difficult conceptual questions. By showing how learners react affectively, cognitively, and metacognitively when provided with information of this kind, these results also suggest that this psychophysiological information can be used productively by learners to optimize learning gains. Given that associations between psychophysiological patterns and emotions are not easily disambiguated especially when considering more complex emotions (see Kreibig, 2010) such as those of interest in educational settings (see Pekrun, 2010), skin conductance measures should be coupled with other measures such as respiration and heart rate (Gomez, Zimmermann, Schär, & Danuser, 2009; Riganello, Garbarino, & Sannita, 2012).

The list of validated psychophysiological measures of cognitive and affective states that can be measured continuously during a learning interaction appears relatively short at this time, but the centrality of those constructs for learning allows for a productive and multifaceted research agenda. However, a shift in EEG signal analysis from (whole head) spectral analysis to source localization in the time-frequency domain (Astolfi, Cincotti, et al., 2010) will very likely yield many additional measures; this approach enables the measurement of sequences of activation in different, specific regions of the brain. These sequences of activation concern higher-order cognitive functions, such as aspects of problem-solving (Anderson, Fincham, Schneider, & Yang, 2012; Grabner & De Smelt, 2012). Finally, measuring brain activity in two participants using the recent technique of hyperscanning (Astolfi, Toppi, et al., 2010) in relationship with novel analysis algorithms such as cross-recurrence quantification analysis (Furasoli, Konvalinka, & Wallot, 2014) may be productive within a view of collaborative learning as joint monitoring and regulation, as suggested in this chapter.

Conclusion: Expected Outcomes

The goal pursued in this work was to suggest a new research approach in collaborative learning involving psychophysiological measurement by showing how the state of the art in pertinent fields can converge productively in the study of current issues in collaborative learning research and implementation. On the basis of current literature, it was suggested that the approach outlined is feasible from a technical point of view. In conceptual and operational terms, the challenges include extending the measurement of individual constructs to multi-agent settings and the measurement of emergent properties of the inter-individual interaction that go beyond the covariation of individual processes. Overall, the potential of this approach underscores a pressing need for theoretical developments: convincing research will have to be based on strong theoretical claims about the functional relationships between psychophysiological processes and cognition and affect in learning that are resistant to the settings, thus securing the ecological validity needed in applied educational research. To this end, recent and upcoming developments in cognitive architectures will have to be closely monitored and integrated in this emerging work. This should lead to important research into how learning settings including collaborative learning influence top-down effects on learning (Clark, 2013a, 2013b; Goswami, 2011) and produce incremental change in learning over time (Anderson, 2002). Thus, the inclusion of social aspects (Howard-Jones, 2011) as well as processes occurring over longer temporal episodes (Anderson, 2002) in the development of cognitive architectures is key in increasing the ecological validity of educational neuroscience research.

The approach outlined could contribute significantly to explorations of important constructs in collaborative learning such as distributed cognition, distributed affect, and joint action. For example, the further study of the hypotheses examined by Gadgil and Nokes-Malach (2012) regarding collaborative inhibition and error detection and correction in collaborative learning would benefit from this approach. Indeed, online psychophysiological measures could complement conversation data and help show true episodes of collaborative inhibition and error detection, during which co-learners have something to contribute but cannot because of the limited bandwidth of conversation (i.e., people cannot talk at the same time). Particularly, the recent demonstration that two brains act as one unified processing system in joint performance (Koike et al., 2015) and that psychophysiological processes interact between individuals in isomorphic or complementary roles (Konvalinka et al., 2011) provides a conceptual and empirical stepping ground for the exploration of this principle in significant contexts of human activity such as collaborative learning. Globally, this firstly involves providing meaningful indexes of learning context, providing sound indexes of affective and cognitive processes in individuals and groups, and providing fine-grained indicators of learning. Secondly, this involves hypothesizing and testing correlational and causal relationships between these elements.

This chapter should contribute to frame projected studies that will examine how intra- and inter-level relations would determine the regulation of inter-agent interactions in a learning context, and their effects on students' learning. An important assumption underlying the propositions in this article is that shortcomings in co-learners' regulation largely emanate from a lack of pertinent information, which seriously undermines the protagonists' agency toward jointly attaining and maintaining cognitive and affective states conducive to learning. A corollary is that providing more information should lead to better joint performance through increased and more precise monitoring (De Bruin, 2012). The field of CSCL is currently addressing this issue: according to Järvelä and Hadwin (2013), CSCL supports include structuring supports, co-learners mirroring, visualization supports, metacognitive awareness tools, and finally guiding tools. In terms of structuring supports, the approach envisioned can contribute insights in the design of collaboration scripts notably by extending them to the affective facet of learning. However, it is probably concerning co-learners' mirroring and visualization supports and metacognitive awareness tools that this approach will provide applied results in the short term. This type of support is based on the tracking, interpretation, and provision of pertinent data about the leaners and regarding individual and collective behavior. According to the notion of cognitive architecture, records integrating psychophysiological data may in principle fruitfully complement conventional data such as conversation and performance traces with indexes that are more fine-grained and more complete than behavioral data. Such information can go beyond task performance and tool use and include indexes of cognitive and affective functioning. Given that the objectivity of these measures is accompanied by a certain amount of reductionism compared to self-report data, the challenge is to provide unequivocal evidence that the interpretation of the information provided to learners can be trusted and acted upon. Finally, guiding tools take the benefits and challenges of this approach a step further by providing scaffolding and feedback to the co-learners on the basis of this information, which according to Järvelä and Hadwin (2013) should be faded as soon as possible to increase learners' empowerment and minimize their dependency on the tool.

The review of available research presented in this work has identified aspects of the collaborative learning situation critical for learning. Recent contributions from neuroscience including methodological advances and computing efficiency make it possible to measure, interpret, and display some of those aspects during the course of a tutorial interaction in ways that complement information obtained from the behavioral observations of the other and from monitoring one's own internal cognitive and affective states. Such a possibility raises many questions.

One of the most important concern in the use of additional sources of complex data is whether or not co-learners can use this additional information productively. It can be expected that this capacity is a skill with a specific learning curve that remains to be established empirically, along with the associated cost in cognitive load. The delivery format and the quantity of variables are also empirical questions. Yet other questions, to which many researchers are already trying to answer, concern what information is most useful and how best to use it. Another question is the extent to which information derived from psychophysiological data can augment awareness and enables associations with concurrent behavior, so that benefits from psychophysiological monitoring can persist when such monitoring is withdrawn.

The projected research agenda is part of a recent trend aiming at using psychophysiological measurement in increasingly authentic real-world settings such as work environments (Parasuraman, 2012) and learning contexts (Galan & Beal, 2012). This endeavor implies dealing with imperfect data with all sorts of contamination, and with confounding factors arising from naturalistic settings. Precautions must be taken in the transformation, analysis procedure, and interpretation of the psychophysiological data. It is also necessary to rely on a variety of approaches in relating this data with behavioral and contextual events, including prevalence, co-occurrence, and sequential across various time scales and levels of analysis (Baker, D'Mello, Rodrigo, & Graesser, 2010; Hruby, 2012; Kapur, 2011; Reimann, 2009; Turner, 2012). The idea of trajectories of learning and research on instructional design constantly hinge on modeling the context of the collaborative learning interaction as past, present, and future dynamic states and its effects on individual and inter-individual processes, a problem that has remained largely outside the realm of quantitative research and thus of causal or even correlational explanations. It is encouraging that 60% of EEG data collected in challenging real-world circumstances (drinking, eating, and talking) can be interpreted using the simplest spectral analysis techniques (Gevins et al., 2012). Laboratory work is needed to establish a robust theoretical and methodological framework; ecologically valid experiments hinge on psychophysiological metrics carefully validated in highly controlled conditions, which are then shown to reflect the same constructs in the intended contexts of use. This process involves translating findings across a cascade of many disciplines, from neuroscience, cognitive neuroscience, psychology, to education, before applying them in the classroom (Tommerdahl, 2010). It is likely that many techniques will be needed and used concomitantly to measure affect and cognition in collaborative learning interactions in conjunction with their effects on learning, as the field transitions to more process-oriented characterization of regulation (Kapur, 2011) and strives to formulate causal relationships with learning outcomes (Panadero & Järvelä, 2015). In sum, here are the main take-home messages of this chapter:

- Many variables and metrics studied in cognitive and affective neuroscience are determinant for learning and have the potential to move collaborative learning research forward by complementing the information naturally available from behavioral data in the modeling of learning interactions.
- The potential of an approach involving psychophysiological and behavioral data continuously over time underscores a pressing need for theoretical developments: convincing research will have to be based on strong theoretical claims about the functional relationships between psychophysiological processes and cognition and affect in learning that are resistant to the various settings of experimentation, thereby contributing to securing the ecological validity needed in educational research.

- It is likely that the many techniques explored in this work will be needed and used concomitantly to measure affect and cognition in collaborative learning interactions in conjunction with their effects on learning, as the field transitions to more process-oriented characterization of regulation (Kapur, 2011) and strives to formulate causal relationships with learning outcomes.

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Chapter 2
An Ensemble-Based Semi-Supervised Approach for Predicting Students' Performance

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Introduction

Educational data mining (EDM) is a growing academic research area, which aims to gain significant insights on student behavior, interactions, and performance and to improve the technology-enhanced learning methods in a data-driven way by applying data mining methods on educational data (Bousbia & Belamri, 2014). During the last decade, research has been focused to enhance the learning experience and institutional effectiveness by merging the computer-assisted learning systems and automatic analysis of educational data. EDM can offer opportunities and great potentials to increase our understanding about learning processes to optimize learning through educational systems. These opportunities have been strengthened by a huge shift in the availability of the data resources, which constitute an inspiring motivation for growing research in this academic research area. In this regard, EDM can be utilized to inform and support learners, teachers, and their institutions and therefore help them understand how these powerful tools can lead to huge benefits in learning and success in educational outcomes, through personalization and adaptation of education based on the learner's needs (Greller & Drachsler, 2012).

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In Greece, like in most countries, secondary education takes place after 6 years of primary education and may be followed by higher education or vocational training. Its main objectives are to engender a balanced and all-round development of the students' personality at a cognitive and emotional level. It comprises two main stages: Gymnasium and Lyceum. Gymnasium covers the first 3 years with the purpose to enrich students' knowledge in all fields of learning and support the development of composite and critical thinking. The next 3 years are covered by Lyceum which further cultivates the students' personalities while at the same time prepares them for admission in higher education. Essentially, Lyceum acts like a bridge between school education and higher learning specializations that are offered by universities.

In the end of the first grade of Lyceum (A′ Lyceum), the students are obligated to select between three directions: humanity, science, and technology. This selection establishes the courses, which the students will attend in the Panhellenic national examinations in order to proceed to the higher education. In this regard, the students' entry into a specific higher educational institution is mainly based on the orientation and group chosen. 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 and the educational institutes. More comprehensively, the "knowledge discovery" can assist students to have a first evaluation of their progress and possibly enhance their performance and teachers to conduct their classes better, identifying difficulties and improving their teaching methods. Thus, it is of major importance to closely monitor the students' performance in order to identify possible retardation and proactively intervene towards their academic enhancement through the assignment of extra learning material, small group training, etc. Nevertheless, the early identification of students who are likely to exhibit 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 (Livieris, Drakopoulou, Kotsilieris, Tampakas, & Pintelas, 2017; Livieris, Drakopoulou, & Pintelas, 2012; Livieris, Mikropoulos, & Pintelas, 2016).

A workable solution to prevent this trend is to analyze and exploit the knowledge acquired from students' academic performance records. In this context, many researchers in the past have conducted studies on educational data in order to cluster students based on academic performance in examinations. However, most of these studies examine the efficiency of supervised classification methods, while the ensemble methods (Gandhi & Aggarwal, 2010; Kotsiantis, Patriarcheas, & Xenos, 2010; Livieris et al., 2016, 2017) and semi-supervised methodologies (Kostopoulos, Kotsiantis, & Pintelas, 2015; Kostopoulos, Livieris, Kotsiantis, & Tampakas, 2017) have been rarely applied to the educational field. Semi-supervised methods and ensemble methods are two important machine learning techniques. The former attempt to achieve strong generalization by exploiting unlabeled data, while the latter attempt to achieve strong generalization by using multiple learners. 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 (2011) presented that semi-supervised learning algorithms and ensemble learning algorithms are indeed beneficial to each other, and more efficient and robust classification algorithms can be developed. More specifically, semi-supervised methodologies could be useful to ensemble methodologies since:

1. Unlabeled data can enhance the diversity of individual classifiers.
2. The lack of labeled examples can be exploited by utilizing unlabeled ones.

Furthermore, the combination of individual classifiers could assist semi-supervised methods since:

1. An ensemble of classifiers could be more accurate than an individual classifier.
2. The performance of the ensemble classifier could be significantly improved using unlabeled data.

In this work, we propose a new ensemble-based 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. Our objective and expectation is that this work could be used as a reference for decision-making in the admission process and to provide better educational services by offering customized assistance according to students' predicted performance.

The remainder of this chapter is organized as follows: Section "A Review of Semi-supervised Machine Learning Algorithms" presents a brief discussion of the semi-supervised learning algorithms utilized in our framework. Section "Literature Review on Educational Data Mining" reviews the related work of other researchers in the area of machine learning algorithms for prediction and classification in education. Section "Proposed Methodology" presents the educational dataset utilized in our study and our proposed ensemble-based semi-supervised learning algorithm, which is compared with the most popular classification algorithms by conducting a series of tests. Finally, the last section considers the conclusions and some further research topics for future work.

A Review of Semi-supervised Machine Learning Algorithms

Semi-supervised learning (SSL) consists of a mixture of supervised and unsupervised learning, aiming to obtain better classification results and performance by exploiting the explicit classification information of labeled data and the information hidden in the unlabeled data. SSL algorithms have become a topic of significant research as an alternative to traditional methods of machine learning, which exhibit remarkable performance over labeled data but lack the ability to be applied on large amounts of unlabeled data. The general assumption of SSL algorithms is that data points in a high-density region are likely to belong to the same class and the decision boundary lies in low-density regions (Zhu, 2006). Therefore, these methods have the advantage of reducing the effort of supervision to a minimum while still preserving competitive recognition performance.

More specifically, SSL methods utilize only a small proportion of the whole amount of data to be labeled for accomplishing their task. This attribute known as labeled ratio R is defined by

$$R = \frac{\text{Number of labeled instances}}{\text{Number of all instances}}$$

and it is usually provided in percentage values (%). Next, after the labeled ratio is defined, all the available data are split into two distinct subsets: the labeled and the unlabeled set.

In the literature, several semi-supervised algorithms have been proposed so far with different philosophy and performance and have been successfully applied in many real-world applications (Chapelle, Scholkopf, & Zien, 2009; Kostopoulos et al., 2015, 2017; Levatic, Dzeroski, Supek, & Smuc, 2013; Liu & Yuen, 2011; Sigdel et al., 2014; Triguero, Saez, Luengo, Garcia, & Herrera, 2014; Wang & Chen, 2013; Zhu, 2006, 2011). Based on their experimental results, many researchers have stated that the classification accuracy can be significantly improved if a large number of unlabeled data are used together with a small number of labeled data. We refer the reader to Pise and Kulkarni (2008), Triguero and Garcıa (2015), and Zhu (2006) and the references therein, for an overview on semi-supervised learning methods and their applications.

In this study, we investigate the classification accuracy utilizing the most famous and frequently used semi-supervised learning techniques: self-training, co-training, and tri-training, which constitute the most representative SSL algorithms.

Self-Training

Self-training is a wrapper-based semi-supervised approach which constitutes an iterative procedure of self-labeling unlabeled data. It has been established as a very popular algorithm due to its simplicity, and it is often found to be more efficient and more accurate than other semi-supervised algorithms (Kostopoulos et al., 2015; Roli & Marcialis, 2006; Sigdel et al., 2014). According to Ng and Cardie (2003), "self-training is a single-view weakly supervised algorithm." Initially, an arbitrary classifier is trained with a small amount of labeled data, which have been randomly chosen from the training set. Subsequently, the training set is iteratively augmented gradually using a classifier trained on its own most confident predictions. More specifically, each classified unlabeled instance that has achieved a probability value over a defined threshold c is considered sufficiently reliable to be added to the training set for the following training phases. Finally, these instances are added to the initial training set, increasing in this way its efficiency and robustness. Therefore, the retraining of the classifier is done using the new enlarged training set until stopping criteria are satisfied.

An important reason why performance may fluctuate compared with supervised algorithms' performance is the fact that, during the training phase of the former, some of the unlabeled examples will not get labeled, since the termination of the algorithm will have been preceded (Schwenker & Trentin, 2014). However, since the success of the self-training algorithm is heavily dependent on its own predictions, its weakness is that erroneous initial predictions will probably lead the classifier to generate incorrectly labeled data (Zhu & Goldberg, 2009).

Co-training

Co-training is a semi-supervised algorithm which can be considered as a different variant of self-training technique (Blum & Mitchell, 1998). The underlying assumptions of the co-training approach are that feature space can be split into two different conditionally independent views and that each view is able to predict the classes perfectly (Du, Ling, & Zhou, 2011; Sun & Jin, 2011). Under these assumptions, co-training algorithm assumes that it is more effective to predict the unlabeled instances by dividing the features of data into two separable categories. In this framework, two classifiers are used. One classifier is trained on each subset, and then the classifiers teach each other with a respective subset of unlabeled examples with the highest confidence predictions. Subsequently, each classifier is retrained with the additional training examples given by the other classifier, and the process is repeated.

Blum and Mitchell (1998) analyzed the classification performance and effectiveness of co-training and disclosed that if the two views are conditionally independent, the predictive accuracy of an initially weak learner can be boosted to arbitrarily high using unlabeled data by co-training. Nevertheless, the assumption about the existence of sufficient and redundant views is a luxury hardly met in most scenarios; several extensions of this algorithm have been developed such as tri-training.

Tri-training

Tri-training algorithm has been originally proposed for solving the problem of co-training since it requires neither two views nor special learning algorithms. This algorithm attempts to exploit unlabeled data utilizing three classifiers. However, such a setting tackles the problem of determining how to efficiently select most confidently predicted unlabeled examples to label. Therefore, in order to make the three classifiers diverse, the original labeled set is bootstrap sampled (Efron & Tibshirani, 1993) to produce three perturbed training sets, on each of which a classifier is then generated and avoids estimating the predictive confidence explicitly. Subsequently, in each tri-training round, if two classifiers agree on the labeling of an unlabeled instance while the third one disagrees, then these two classifiers will label this instance for the third classifier. It is worth noticing that the "majority teach minority strategy" serves as an implicit confidence measurement, which avoids the use of complicated time-consuming approaches to explicitly measure the predictive confidence, and hence the training process is efficient.

However, sometimes the performance of tri-training degrades; hence three other issues must be taken into account (Guo & Li, 2012):

1. Estimation of the classification error is unsuitable.
2. Excessively confined restrictions introduce further classification noise.
3. Differentiation between initial labeled example and labeled of previously unlabeled example is deficient.

Literature Review on Educational Data Mining

During the last decade, the application of data mining for the development of accurate and efficient decision support systems for monitoring students' performance is becoming very popular in the modern educational era. A large proportion of these studies examines the efficiency of supervised classification methods, while ensemble and SSL methodologies have been rarely applied to the educational field. Some excellent reviews (Baker & Yacef, 2009; Pena-Ayala, 2014; Romero & Ventura, 2007, 2010) provide a comprehensive resource of papers on EDM, which present a detailed description of the mining learning data process, covering the application of EDM from traditional educational institutions to web-based learning management systems and intelligently adaptive educational hypermedia systems. Moreover, they present how EDM seeks to discover new insights into learning with new tools and techniques, so that those insights impact the activity of practitioners in all levels of education, as well as corporate learning. A number of rewarding studies have been carried out in recent years and some of them are presented in this section.

Kotsiantis, Pierrakeas, and Pintelas (2003, 2004) studied the accuracy of six common machine learning algorithms in predicting students that tend to drop out from a distance learning course in the Hellenic Open University. Based on previous works, Kotsiantis et al. (2010) proposed an online ensemble of supervised algorithms to predict the performance on the final examination test (pass/fail) of students attending distance courses in higher education. The proposed ensemble of classifiers outperformed classical well-known algorithms and could be utilized as a predictive tool from tutors during the academic year to underpin and boost low performers.

Thai-Nghe, Janecek, and Haddawy (2007) attempted to predict the performance of undergraduate and postgraduate students at two academic institutes using machine learning techniques. Along this line, Thai-Nghe, Busche, and Schmidt-Thieme (2009) presented an extensive study to deal with the class imbalance problem in order to improve the prediction results of academic performances. Firstly, they balanced the datasets and then they used both cost-insensitive and cost-sensitive learning with a support vector machine for the small datasets and decision tree for the larger datasets which provided satisfactory classification results.

Cortez and Silva (2008) predicted the student grades for two core classes (Mathematics and Portuguese) from two secondary schools. The data were extracted from school records, as well as provided by the students through questionnaires. They applied four classification algorithms on three data setups, with different combinations of attributes, trying to find out those with more effect on the prediction. Based on their numerical experiments, the authors concluded that the students' achievements are more related with their performance in the past years and less correlated with their social and cultural characteristics.

Gandhi and Aggarwal (2010) presented a methodology based on the assessment of their past performance as well as on their respective learning curves constructed over time to predict the future performance of students. More specifically, they applied the Rasch model technique to capture the effects of student level proficiency and steps' level difficulty. They demonstrated robust validation results from hybrid ensemble of logistic regression models and also discussed the scope of improved models with segmentation analysis.

Ramaswami and Bhaskaran (2010) presented the CHi-squared Automatic Interaction Detector (CHAID) prediction model, which was utilized to analyze the interrelation between variables that were used to predict the performance at higher secondary school education. The CHAID prediction model of student performance was constructed with seven class predictor variables. Their study showed that features, which constitute the strongest indicators, are marks in written assignments and tests, school location, living area, and the type of secondary education.

Independently, Ramesh, Parkav, and Rama (2013) tried to identify the factors influencing the students' performance in final examinations based on a dataset including questionnaire data and students' performance details. Their primary task was identifying the essential predictive variables, which affect the performance of higher secondary students, predict the grade at higher examinations, and determine the best classification algorithm. Their comparative study revealed that parent's occupation and possibly financial status plays a major role in the students' performance. Furthermore, their numerical experiments showed that the multilayer perceptron exhibited the best classification accuracy.

Livieris et al. (2012) introduced a software tool for predicting the students' performance in the course of "Mathematics" of the first year of Lyceum. The proposed software is based on a neural network classifier, which exhibits more consistent behavior and illustrates better accuracy than the other classifiers. Along this line, Livieris et al. (2016) presented a user-friendly decision support software for predicting students' performance, together with a case study concerning the final examinations in Mathematics. Their proposed tool is based on a hybrid predicting system, which combines four learning algorithms utilizing a simple voting scheme. In more recent works, Livieris et al. (2017) presented an updated version, which is based on a novel two-level classification algorithm, which achieves much better classification performance than any single classifier. 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. Based on their preliminary results and on the comments made by the high school educators, the authors concluded that the application of data mining can provide significant insights into student progress and performance.

Recently, semi-supervised methods have been applied to predict the student's future progression and identity their characteristics, which induce their behavior and performance. More specifically, Kostopoulos et al. (2015) 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 very promising results, especially the self-training and the tri-training algorithm. Based on the previous works, Kostopoulos et al. (2017) 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.

Proposed Methodology

The motivation for this study is to develop a methodology for predicting the students' performance in the final examinations of A′ Lyceum, exploiting the effectiveness of semi-supervised methods. Apparently, this methodology is not restricted to A′ Lyceum but extends to any final examinations. For this purpose, we propose the following methodology which consists of three stages.

The first stage of the proposed methodology concerns the data collection and data preparation for this research. In the next stage, we present our proposed ensemble-based SSL algorithm. Finally, in the third stage, we compare our proposed ensemble-based semi-supervised algorithm with the most popular SSL algorithms by conducting a series of tests.

Data Collection and Preparation

In this study, we have utilized a dataset concerning the performance of 799 students in courses of "Mathematics" which have been collected by the *Microsoft showcase school* "Avgoulea-Linardatou" during the years 2012–2016. At this point, we recall that we have selected the course of "Mathematics" since it has been characterized as the most significant and most difficult course of the Science direction. Table 2.1 presents eleven (11) attributes, which characterize the performance of each student in each class of the first 4 years of high school. They are based on several written assignments and frequent oral questions, which assess students' understanding of important mathematical concepts and topics daily.

Table 2.1 Attributes description for each class

Attribute	Type	Values
Oral grade of the first semester	Integer	[0, 20]
Grade of the first test of the first semester	Real	[0, 20]
Grade of the second test of the first semester	Real	[0, 20]
Grade of the final examination of the first semester	Real	[0, 20]
Grade of the first semester	Integer	[0, 20]
Oral grade of the second semester	Integer	[0, 20]
Grade of the first test of the second semester	Real	[0, 20]
Grade of the second test of the second semester	Real	[0, 20]
Grade of the final examination of the second semester	Real	[0, 20]
Grade of the second semester	Integer	[0, 20]
Grade in the final examinations	Ordinal	"Fail," "good,"
		"Very good," "excellent"

The first 10 values are time-variant attributes and 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. Many related studies have shown that such attributes have a significant impact in students' success in the examinations (Cortez & Silva, 2008; Livieris et al., 2012, 2016; Ramaswami & Bhaskaran, 2010). The assessment of students during the academic year consists of oral examination, two 15-min pre-warned tests, a 1-h exam, and the overall semester performance of each student in the first and second semester. The 15-min tests include multiple-choice questions and short-answer problems, while the 1-h exams include several theory and multiple-choice questions, as well as a variety of difficult mathematical problems requiring arithmetic skills, solving techniques, 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) utilizing a four-level classification, according to the classification scheme used in students' performance evaluation in the Greek schools, namely:

- "Fail" stands for student's performance between 0 and 9.
- "Good" stands for student's performance between 10 and 14.
- "Very good" stands for student's performance between 15 and 17.
- "Excellent" stands for student's performance between 18 and 20.

Figure 2.1 presents the class distribution which depicts the number of students who are classified as "Fail" (178 instances), "Good" (202 instances), "Very good" (178 instances), and "Excellent" (241 instances).

Furthermore, similar to Livieris et al. (2012, 2016, 2017), since it is of great importance to predict students' performance at the final examination of A′ Lyceum as soon as possible, two datasets have been created based on the attributes presented in Table 2.1:

- $DATA_1$: It contains the attributes which concern the students' performance in A′, B′, and C′ Gymnasium (3 × 11 attributes + class).

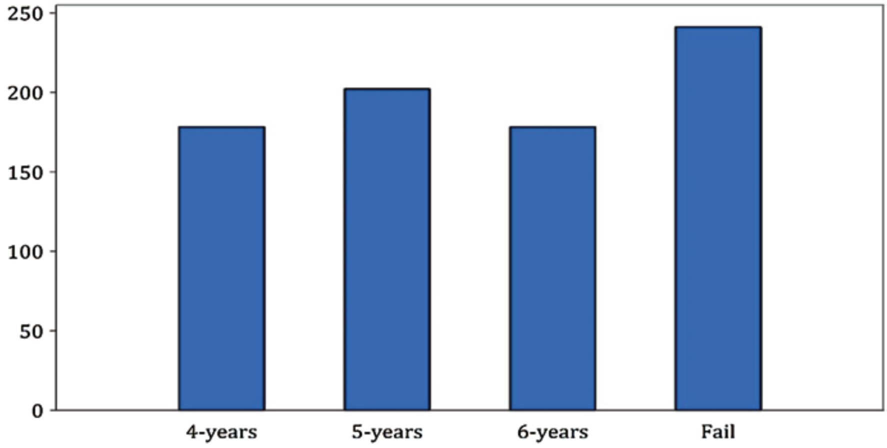

Fig. 2.1 Class distribution

- $DATA_2$: It contains the attributes which concern the students' performance in A′, B′, and C′ Gymnasium and A′ Lyceum (3 × 11 attributes + 10 attributes+ class).

The Proposed Ensemble-Based Semi-supervised Classifier

Our goal is to develop a classifier with strong classification ability by hybridization of ensemble learning and semi-supervised learning. We recall that SSL algorithms could be useful to ensemble learning algorithms since unlabeled data can enhance the diversity of individual classifiers and the lack of labeled examples can be exploited by utilizing unlabeled ones. Furthermore, ensemble learning methodologies could assist SSL since the combination of classifiers could be more accurate than an individual classifier and the performance of the ensemble classifier could be significantly improved using unlabeled data.

On the basis of this idea, we consider utilizing an ensemble of classifiers as a single base learner, instead of a single classifier, in each SSL algorithm. Generally, the development of an ensemble of classifiers consists of two steps: selection and combination. The selection of the appropriate component classifiers is considered to be an essential step towards obtaining highly accurate classifier systems (Zhou, 2011). A commonly used approach is to generate an ensemble of classifiers by applying diverse learning algorithms (with heterogeneous model representations) to a single dataset (see Merz, 1997, 1999; Todorovski & Džeroski, 2002). Furthermore, the combination of the individual predictions of learning algorithms takes place through several methodologies (see Dietterich, 2001; Re & Valentini, 2012; Rokach, 2010).

In this regard, our proposed ensemble-based classifier combines the individual predictions of three learning algorithms via a simple majority voting; hence the ensemble output is the one made by more than half of them. This selection constitutes the simplest and easiest implementation methodology for combining the individual predictions of component classifiers. The advantages of this technique are that it exploits the diversity of the errors of the learned models by utilizing different learning algorithms (Merz, 1997, 1999) and it does not require training on large quantities of representative recognition results from the individual classifiers. Moreover, several studies have reported that majority voting usually exhibits very good classification performance, developing highly accurate classifiers (Lam & Suen, 1997; Livieris et al., 2016; Matan, 1996).

Table 2.2 presents a high-level description of our proposed scheme, which utilizes an ensemble-based learner in any SSL algorithm.

Experimental Results

In this section, we conduct a series of tests in order to evaluate the performance of the SSL algorithms self-training, co-training, and tri-training deploying the most popular supervised classifiers as base learners. The selected supervised classifiers are the Naive Bayes (NB) (Domingos & Pazzani, 1997), the multilayer perceptron (MLP) (Rumelhart, Hinton, & Williams, 1986), the sequential minimal optimization (SMO) (Platt, 1999), the logistic model tree (LMT) (Landwehr, Hall, & Frank, 2005), and the PART (Frank & Witten, 1998) as the representative of the classification rules. Finally, 3-NN algorithm was selected as instance-based learner (Aha,

Table 2.2 Ensemble-based semi-supervised learning algorithm

Input:	*D*—Initial training dataset
	R—Ratio of labeled instances along *D*
	C_i—User selected classifiers, $i = 1, 2, 3$
/* Initialization phase */	
1:	Set of labeled training instances *L*
2:	Set of unlabeled training instances *U*
3:	Set the ensemble-base classifier *E*, using majority vote of individual classifiers C_1, C_2, C_3
/* Training phase */	
4:	Repeat
5:	Train *E* as base learner on *L* using any SSL algorithm
6:	Apply *E* on the unlabeled data *U*
7:	Add selected newly labeled data from *U* to the training set *L*
8:	Until some stopping criterion is met
Output:	Use trained ensemble *E* to predict class labels of the test cases
Remarks:	In step 5, the selected SSL algorithm is one of self-training, co-training, and tri-training

1997). Several studies have shown that the above classifiers constitute some of the most effective and frequently utilized data mining algorithms (Wu et al., 2008).

The classification accuracy of all learning algorithms was evaluated utilizing the standard procedure called stratified tenfold cross-validation, i.e., the data were separated into folds so that each fold had the same distribution of grades as the entire dataset. Furthermore, the implementation code was written in JAVA, using WEKA Machine Learning Toolkit (Hall et al., 2009), and all the base learners were utilized with default parameter settings.

Tables 2.3, 2.4, and 2.5 present the classification performance of each test algorithm utilizing 10%, 20%, and 30%, respectively, as labeled data ratio, and the best accuracy among the different algorithms in each experiment is highlighted in bold style. The aggregated results presented in Tables 2.3, 2.4, and 2.5 show that LMT exhibits the best classification performance utilized as base classifier followed by SMO and PART, relative to all SSL algorithms.

Table 2.3 Comparison of accuracy of self-training algorithms

		Self-training algorithm					
Dataset	Ratio	(NB)	(MLP)	(SMO)	(LMT)	(PART)	(3NN)
$DATA_1$	10%	69.90%	72.88%	70.98%	**81.47**%	74.30%	69.05%
	20%	69.16%	73.65%	74.39%	**81.85**%	76.23%	71.01%
	30%	70.67%	72.54%	72.09%	**82.62**%	76.98%	67.99%
$DATA_2$	10%	76.31%	78.23%	**80.77**%	79.22%	79.30%	75.46%
	20%	77.08%	76.99%	78.19%	**81.51**%	79.69%	75.87%
	30%	77.46%	78.56%	77.41%	**78.83**%	73.99%	71.65%

Table 2.4 Comparison of accuracy of co-training algorithms

		Co-training algorithm					
Dataset	Ratio	(NB)	(MLP)	(SMO)	(LMT)	(PART)	(3NN)
$DATA_1$	10%	70.66%	72.11%	67.19%	**81.50**%	75.44%	70.24%
	20%	69.10%	73.33%	71.42%	**77.35**%	75.88%	69.47%
	30%	71.03%	71.74%	72.45%	**80.30**%	76.24%	67.65%
$DATA_2$	10%	75.61%	78.58%	76.30%	**78.50**%	76.99%	72.11%
	20%	75.94%	77.76%	73.21%	**79.19**%	76.65%	72.81%
	30%	75.19%	76.99%	75.53%	**80.36**%	77.41%	74.36%

Table 2.5 Comparison of accuracy of tri-training algorithms

		Tri-training algorithm					
Dataset	Ratio	(NB)	(MLP)	(SMO)	(LMT)	(PART)	(3NN)
$DATA_1$	10%	69.90%	70.68%	73.99%	78.19%	**78.39**%	68.38%
	20%	69.53%	70.64%	70.28%	**81.47**%	74.33%	70.60%
	30%	69.90%	73.29%	72.52%	**81.10**%	75.85%	72.05%
$DATA_2$	10%	76.32%	78.48%	**78.87**%	78.57%	76.24%	73.58%
	20%	76.71%	77.05%	78.87%	**79.60**%	79.26%	75.87%
	30%	75.20%	78.50%	77.74%	**81.17**%	79.27%	77.35%

Subsequently, we evaluate the performance of our proposed SSL algorithm, which utilizes an ensemble as base classifier (denoted as Vote). The ensemble-based learner combines the individual predictions of three classifiers (LMT, PART, and SMO) using majority vote. Notice that these classifiers have been selected since they exhibit the best classification performance, regarding both datasets. Moreover, the performance of the proposed algorithm is compared against the best reported performance of all base learners (denoted as Best) for each SSL algorithm. As before, the accuracy measure of the best performing algorithm is highlighted in bold for each base learner and on each dataset. Additionally, a more representative visualization of the classification performance of the compared base learners for each SSL algorithm is presented in Figs. 2.2, 2.3, and 2.4.

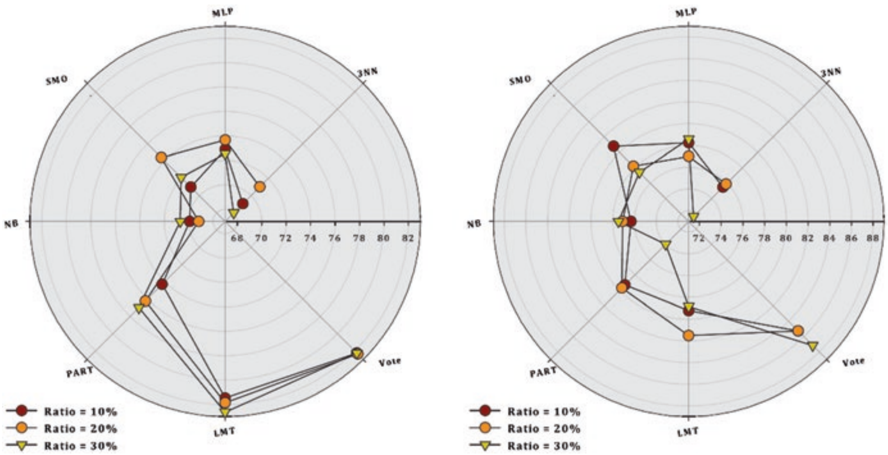

Fig. 2.2 Comparison of average accuracy of self-trained classifiers on $DATA_1$ and $DATA_2$

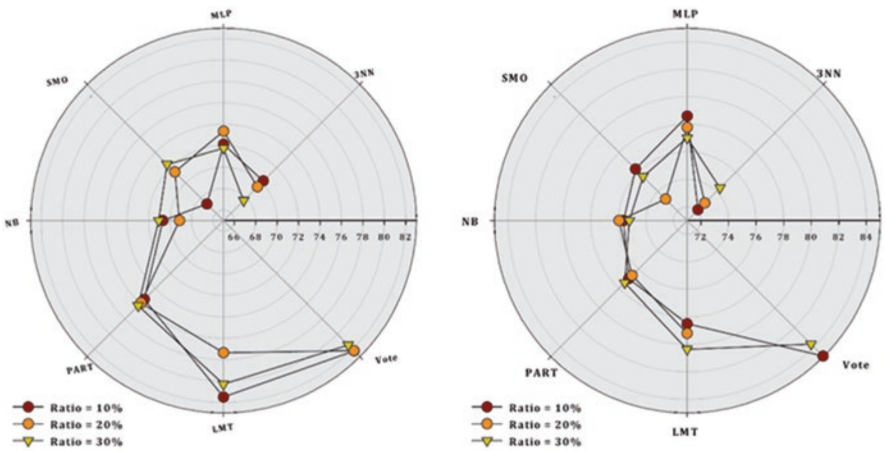

Fig. 2.3 Comparison of average accuracy of co-trained classifiers on $DATA_1$ and $DATA_2$

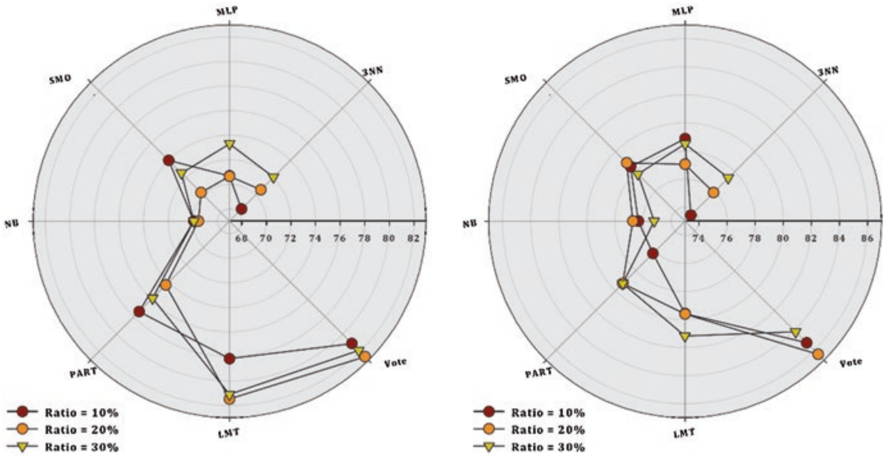

Fig. 2.4 Comparison of average accuracy of tri-trained classifiers on $DATA_1$ and $DATA_2$

Table 2.6 Comparison of accuracy of SSL algorithms

Dataset	Ratio	Self-training (Best)	Self-training (Vote)	Co-training (Best)	Co-training (Vote)	Tri-training (Best)	Tri-training (Vote)
$DATA_1$	10%	81.47%	**82.24%**	81.50%	**82.21%**	78.39%	**81.07%**
	20%	81.85%	**82.34%**	77.35%	**82.19%**	81.47%	**82.59%**
	30%	**82.62%**	82.24%	80.30%	**81.45%**	81.10%	**81.87%**
$DATA_2$	10%	80.77%	**85.26%**	78.50%	**84.93%**	78.87%	**85.24%**
	20%	81.51%	**85.24%**	79.19%	**85.66%**	79.60%	**86.40%**
	30%	78.83%	**87.15%**	80.36%	**83.70%**	81.17%	**84.13%**

The interpretation of Table 2.6 reveals that Vote presents by far the best classification results utilized as base classifier in all cases except the one when self-training algorithm utilized LMT as base learner with a labeled ratio of 30%. Furthermore, tri-training (Vote) and self-training (Vote) exhibit the best performance relative to $DATA_1$ and $DATA_2$, respectively. An interesting point, which is highlighted in Figs. 2.2, 2.3, and 2.4 is that all the SSL algorithms, which utilize Vote as base classifier, report similar classification results independent of the utilized ratio of labeled data and dataset, assuring their robust behavior.

The statistical comparison of multiple algorithms over multiple datasets is fundamental in machine learning, and usually it is typically carried out by means of a statistical test (Kostopoulos et al., 2015, 2017) Therefore, we utilized the non-parametric Friedman Aligned Ranking (Hodges & Lehmann, 1962) test in order to evaluate the rejection of the hypothesis that all the classifiers perform equally well for a given level. Since the test is non-parametric, it does not require commensurability of the measures across different datasets, it does not assume normality of the sample means, and it is robust to outliers.

Table 2.7 Friedman aligned ranks test (significance level of 0.05)

Self-training		Co-training		Tri-training	
Base learner	Friedman ranking	Base learner	Friedman ranking	Base learner	Friedman ranking
Vote	5.00	Vote	3.83	Vote	4.33
LMT	9.33	LMT	9.83	LMT	9.67
PART	18.67	PART	16.17	PART	17.00
SMO	24.00	MLP	21.83	SMO	24.17
MLP	24.17	SMO	30.83	MLP	26.67
NB	32.00	NB	30.83	NB	33.83
3NN	37.33	3NN	37.17	3NN	34.83

Table 2.7 presents the SSL algorithms ranked from the best performer to the worst. The proposed voting scheme illustrates statistically better classification results among all tested algorithms. More specifically, the base learner Vote reports the best performance due to better probability-based ranking and higher classification accuracy in all SSL algorithms.

Conclusions

In this work, we propose a new ensemble-based SSL method for predicting the students' performance in the final examinations at the end of academic year of A′ Lyceum. Our experimental results reveal that our proposed method is proved to be effective and practical for early student progress prediction as compared to some existing semi-supervised learning methods. Our objective and expectation is that this work could provide prognosis for better educational support by offering customized assistance according to students' predicted performance and be used as a reference for decision-making in the admission process.

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Chapter 3
How Do Transformational Principals View ICT as a Means for Promoting Educational Innovations? A Descriptive Case Study Focusing on Twenty-First Century Skills

Spiridoula Laschou, Vassilis Kollias, and Ilias Karasavvidis

Introduction

Educational systems worldwide face a multitude of challenges on several levels. As a result, educational innovation has been a constant concern for many stakeholders such as teachers, administrators, policy makers, parents, and researchers. The underlying assumption has been that educational problems can—and should—be resolved through innovation. However, despite consistent and concerted efforts originating from many different sources (e.g., local and central educational authorities, parents, interest groups, etc.), educational systems have exhibited remarkable resistance to change (Cuban, 2013; Tyack & Tobin, 1994).

In recent years, the school principal is considered to be one of the key factors for unlocking the educational inertia and improve teaching and learning practices. More specifically, research that focuses on school effectiveness, school improvement, and school innovation highlights the crucial role of the principal (Evans, 1996; Hall & Hord, 2001; Hallinger & Heck, 1996; Pashiardis, 2013; Sarason, 1996). Different styles of principal administration have been distinguished. Bass (1990) distinguished between transactional and transformational ones, the latter being the leaders who "inspire, energize, and intellectually stimulate their employees" (p. 19). Transformational leadership has been suggested as the appropriate leadership style for principals implementing significant educational innovations (Leithwood & Jantzi, 2000). It appears that transformational leadership from the side of the principal is most favorably connected to improved educational outcomes

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(Hoy & Miskel, 2005; Miller & Miller, 2001). According to Miller and Miller (2001), transformational leadership leads to greater dedication, motivation, and morality to the school organization through mutual influence and interaction between principals and teachers.

Furthermore, focusing on ICT integration, one of the factors that have been found to be critical to ICT integration in educational practices is related to school administration (Hayes, 2007; Ilomaki, Lakkala, & Lehtinen, 2004; Law, 2008; Perrotta, 2013; Yee, 2001). School administrators appear to play a crucial mediating role (Anderson & Dexter, 2005; Schiller, 2003). Wilmore and Betz (2000) argued that "Information Technology will only be successfully implemented in schools if the principal actively supports it, learns as well, provides adequate professional development and supports his/her staff in the process of change" (p. 15). Liu (2011) concluded that external forces such as principals are a major motivational force behind technology use in classrooms. Similarly, Wikan and Molster (2011) reported that teachers feel pressure to integrate technology in their practices by principals and other stakeholders.

As many studies have suggested, the degree of ICT uptake in educational systems is rather low (Gray, Thomas, & Lewis, 2010; Hinostroza, Labbé, Brun, & Matamala, 2011; Ward & Parr, 2010; Wikan & Molster, 2011; Zhao & Frank, 2003). On the other hand, whenever ICT gets integrated in educational practices, it is mostly used to sustain rather than transform them (Cuban, 2013; Donnelly, McGarr, & O'Reilly, 2011; Hayes, 2007; Hermans, Tondeur, van Braak, & Valcke, 2008; Law & Chow, 2008; Li, 2007; Player-Koro, 2012; Van Braak, Tondeur, & Valcke, 2004). Transformational leadership has been singled out as a particular form of technology leadership that is strongly related to the use of ICT in education (Ross, McCraw, & Burdette, 2001; Weng & Tang, 2014). Despite the importance of transformational leadership for promoting technology integration, to the best of our knowledge, few studies have explicitly addressed the depth of educational innovation that transformational leaders aspire to achieve through technology integration. The present study focuses on a sample of Greek transformational principals and examines how (a) they view educational innovation and (b) they perceive ICT use in their school as a means to support educational innovation.

Theoretical Framework

Transformational Leadership

As mentioned in the introduction, one type of effective school leader is the transformational principal. Transformational leadership has been defined in a number of ways. In this work, we adopt the definition given by Muijs, Harris, Lumby, Morrison, and Sood (2006): "leadership that transforms individuals and organizations through an appeal to values and long-term goals. In this way, it manages to reach followers and tap into their intrinsic motivation" (p. 88). Bass and Avolio (1993) described transformational leadership as being composed of four unique but interrelated behavioral components: inspirational motivation, intellectual stimulation, idealized influence, and individualized consideration. Theofilidis (2012) identifies the following factors of transformational leadership:

- *Individual support*: Transformational leaders differentiate each individual in the organization (teacher, parent, or student), support their development, and aid them in realizing their potential in the school.
- *Common goals*: Transformational principals focus on constraints and goals that need to be accepted by all the members of the school community. They share their knowledge and vision with others so that the other members of the community follow their lead toward improved learning.
- *Common vision*: Transformational principals promote a common vision in order for school change to take place and for learning to be of high quality (Kurland, Peretz, & Hertz-Lazarowitz, 2010).
- *Intellectual stimulation*: Transformational principals face old problems using new strategies, which leads to new ideas and affordances.
- *Building common culture*: A transformational principal can lead to groundbreaking changes in the culture of the school. Realizing a far-reaching vision, increasing the effectiveness of the school, and achieving high-quality learning become part of the institutional culture of the school.
- *Reward*: Transformational principals provide rewards to the members of the school community to support commitment to the school vision. Recognition of performance is one of the basic rewards that are sought for in schools.
- *High expectations*: Transformational principals look forward to setting high expectations, high moral standards, and high quality motives for the members of the school community (Yukl, 2002).
- *Influential example*: Transformational principals function as exemplary members of the school community. Through his/her example, the principal motivates the members of the school community to follow ideas, beliefs, and knowledge that he/she promotes and that are compatible with the vision for the school.

Educational Innovation

There are many ways to conceptualize educational innovations. For the purposes of this study, we approach educational innovation in terms of twenty-first-century skills (hereafter 21CS). One of the pros of such a conceptualization is the extent to which 21CS are seen as the de facto educational ideal for the coming decades (Halász & Michel, 2011; Partnership for 21st Century Skills; UNESCO, 2017).

There appears to be a significant level of consensus regarding the definition of 21CS. As Dede (2009) remarked: "[research] groups developing conceptualizations of 21st century skills have built sufficiently on each other's ideas to avoid a 'Tower of Babel' situation." In their review of the literature on 21CS, Binkley et al. (2012) identify the following major factors in 21CS:

- *Ways of thinking* (creativity and innovation; critical thinking, problem solving, decision-making; learning to learn, metacognition)
- *Ways of working* (communication; collaboration (teamwork))
- *Tools for working* (information literacy, ICT literacy)
- *Living in the world* (citizenship—local and global, life and career, personal and social responsibility—including cultural awareness and competence)

In this article, we follow Thoma, Karafotia, and Tzovla (2016) in their master list of 21CS which is based on several conceptualizations and combines various proposals (Binkley et al., 2012; Dede, 2009; Partnership for 21st Century Skills). Table 3.1 presents a summary of this list of 21CS, while further description is provided in the remainder of this section.

Critical Thinking and Problem Solving

There are many definitions of critical thinking, but the ability to evaluate, analyze, synthesize, and interpret information is common to all definitions. Openness to new ideas, the ability to concentrate on the issues that are important, knowing oneself and his/her biases, and disciplining oneself into following procedures set by learned

Table 3.1 Dimensions 21CS

Twenty-first-century skill	Dimensions that were compiled from the literature review
Critical thinking, problem solving	Openness to new ideas, concentration, collaboration, evaluation, analyzing, synthesizing, self-knowledge, discipline, interpretation, use of ICT
Learning to learn, metacognition	Critical thinking, autonomy, observation, self-regulation, problem solving
Collaboration (teamwork)	Social awareness, interdependence, interaction, problem solving, critical thinking, information processing, use of ICT
Flexibility and adaptability	Critical thinking, collaboration, dealing with change, finding a middle ground among different opinions
Communication	Critical thinking, collaboration, learning new languages, dialogue, use of ICT
Creativity and innovation	Problem solving, creation of new ideas, self-confidence, dialogue, use of ICT
Information and ICT literacy	Digital literacy, working in groups, evaluation of information, adaptability to new data and evidence, flexibility, innovation
Knowledge building	Creativity, collaboration, interpretation, evaluation, production of new ideas, synthesizing, analyzing
Social and cultural awareness	Collaboration, critical and creative thinking, informed citizens, democratic participation, self-confidence, values

communities are additional features. Finally, nowadays critical thinking is also connected to the appropriate use of ICT and collaboration with peers. All definitions, however, include the ability to collect, evaluate, and efficiently use information. Critical thinking is also related to problem solving (Ananiadou & Claro, 2009).

Learning to Learn, Metacognition

Metacognition is thinking about thinking. Metacognition includes the observation of thinking processes and is related to critical thinking and problem solving. Concern for autonomy and the development of self-regulation skills facilitate the development of metacognition.

Collaboration (Teamwork)

According to Brody and Davidson (1998) Collaboration is characterized by the ability students have to work together in problem solving and to organize their work toward achieving a common goal. High-value collaboration is supported by critical thinking on the work processes and on the quality of interaction, through the processing of relevant information. Interdependence among the members of the team is a helpful prerequisite, while social awareness makes collaboration in diverse groups efficient. Nowadays, ICT is often seen as an essential part of collaborative practices.

Flexibility and Adaptability

Flexibility and adaptability refer to the ability to respond fluently to complex problems. It is related to critical thinking and dealing with change. Moreover, since complex problems nowadays are often addressed by groups of people, it is supported by and developed through collaboration. Finding a middle ground among different opinions is a crucial feature of this skill.

Communication

Communication is one of the most important factors that lead to a climate conducive to learning (Hoy & Miskel, 2005). Dialogue and collaboration facilitate the development of communication skills, while critical thinking of the conditions of dialogue and collaboration further support their development. The use of ICT is nowadays an integral part of the communicative experience, while for EU, the term communication includes learning of both the native language and other languages (Developing key competences at school in Europe, 2012).

Creativity and Innovation

Creativity and Innovation are related concepts (Robinson, 2006). Students are expected to create new ideas in problem solving and to be self-confident in dealing with change. Dialogue is especially important in the seeding and developing of new ideas, and today ICT is providing several tools that can be used to support the development of creativity and innovation.

Information and ICT Literacy

Information and ICT literacy does not only concern digital literacy, but it also includes the use of ICT to support flexibility, to achieve innovation, and to work in groups and the ability to take advantage of new data and evidence through the use of ICT.

Knowledge Building

Knowledge building as a skill involves collaboration with other students for analysis, synthesis evaluation and interpretation of information, and creativity in bringing forth new perspectives, ideas, and solutions.

Social and Cultural Awareness

Social and cultural awareness stems from the current need for citizens to participate in public life on local, national, and global levels. The skill of social and cultural awareness refers to the ability to get informed and participate in dialogue and actions with respect to issues of local and global interest with self-confidence (Partnership for 21st Century Skills). It is also crucial that the future citizen collaborates with and supports members of other cultural communities and to know the rights and obligations in a democratically organized society.

Focus of the Study

This study focuses on transformational principals in Greece and examines their perceptions regarding educational innovation and ICT use. More specifically, the study has two main objectives. First, it aims to determine how transformational principals view educational innovation. Second, it aims to determine how transformational principals view educational innovation in relation to ICT use. Thus, the study addressed the following research questions:

RQ1 *Is there an association between principals' perceptions of transformational leadership and their corresponding perceptions of educational innovation?*

RQ2 *Is there an association between principals' perceptions of transformational leadership and educational innovation with their corresponding perceptions of ICT use in teaching and learning?*

Regarding the first research question, we expected that the transformational character of the principals' leadership conceptions will be positively associated with educational innovation views. Regarding the second research question, we expected that both transformational leadership and educational innovation views will be positively correlated with the principals' views about ICT use in teaching and learning.

Method

Sample

Given the study objectives, the sampling process was as follows. First, the superintendents of a large district in mainland Greece were contacted, and they were provided with the list of the sought-after characteristics of transformational leadership. This list included the properties identified in the preceding section (i.e., providing individual support, helping shape a shared vision and goals, offering intellectual stimulation, building a common culture, providing an influential example, having high expectations, and arranging for rewards). The superintendents were then asked to identify school principals in their district who, in their professional judgment, fitted this profile in the best possible way. Once the superintendents provided us with a list of potential candidates, the corresponding principals were then contacted, briefed about the study, and were asked whether they would be interested in participating. All 15 principals who had been initially identified expressed interest in participating. Table 3.2 provides an overview of the demographic characteristics of the participants.

Data Collection

For the purposes of this study, two types of data were gathered, quantitative and qualitative. The former involved the collection of demographic information. To determine gender, age, work experience, time of service as a principal, education, and further training, each participant was asked to fill in a short questionnaire

Table 3.2 Demographic characteristics of the participants ($N = 15$)

Gender	Age group	Further education	Graduate degrees
Male: 10 Female: 5	35–45: 1 46–56: 13 56+: 1	Further education programs: 15	Master's: 6 PhD: 0

comprised of seven closed questions. The qualitative data collection involved verbal data which were gathered through interviews. More specifically, each participant was interviewed by the first researcher. The interviews were semi-structured, following an interview protocol comprised of six guiding questions (given in the Appendix). The interviews run from half an hour to three quarters of an hour. The interview process was as follows. After establishing rapport, the researcher posed the first question, allowing ample time for each principal to respond in any way he/she wished without any interruptions whatsoever. When the participants had finished responding, the researcher followed up inquiring further elaborations which depended on the topics that the principals had addressed. This procedure was followed for all remaining questions on the interview list. It is important to stress that the interview questions were open-ended and the principals chose both what to respond and how to prioritize their responses. Furthermore, the principals were asked to provide specific examples and elaborate on them using open-ended questions again. All interviews were recorded and transcribed verbatim. The resulting interview transcripts were then subjected to quantitative content analysis as described in the next section.

Analysis

Quantitative content analysis (Chi, 1997; Krippendorff, 1989; Willig, 2013) was used to quantify teacher responses into the following variables: (a) *the degree to which each principal was transformational*, (b) *each principal's conception of each of the nine 21CS, and* (c) *each principal's perceptions of the role of ICT in teaching and learning*. Each quantification served to capture variations in one specific dimension (or factor). Once the three variables were quantified, Spearman's rho correlation coefficient was used to examine correlations among the variables.

Deriving a Transformational Leadership Measure

The interview questions that were related to transformational leadership were questions 1, 2, 3, and 6 (see Appendix). The response to each question was scored for the eight dimensions of transformational leadership (i.e., Individual support, Common goals, Common vision, Intellectual stimulation, Building common culture, Reward, High expectations, and Influential example, see Table 3.1 above). The scoring procedure was binary: each dimension was given a score of 1 if it was present in the principals' response and 0 otherwise. Table 3.3 illustrates an excerpt of the coding scheme used for scoring the transformational dimension "Influential example" in Table 3.3.

Following scoring, the scores across all transformational dimensions were summed to produce an overall measure of how "transformational" each particular

Table 3.3 Coding scheme for "Influential example"

Definition	Value	Example
This dimension is completely absent in the response	0	–
This dimension is mentioned in the response	1	"Some common activities of the staff that were realized outside teaching time improved interpersonal relations. I really put the effort, through my personal example, to achieve a climate of respect, trust, mutual assistance, both among the teachers and between the school personnel and parents and students" [Principal 10]

principal was. Therefore, 4 scores were derived for each principal, each pertaining to one of the corresponding interview questions. Once the scores in transformational leadership for each principal were computed for each of the four questions, Cronbach's alpha was computed to evaluate whether the different questions were actually measuring the same overall construct. The resulting Cronbach's alpha value was 0.665, and we considered it sufficiently high to warrant the creation of an aggregate score across the four questions. Consequently, the resulting mean was used as a reliable indicator of how transformational each principal was.

Deriving a Measure of Principals' Perceptions of 21CS

The interview questions that focused on 21CS are questions 2, 3, and 4 (see Appendix). We followed the same binary scoring procedure as above which is briefly illustrated for the dimension of flexibility and adaptability. More specifically, in each principal's response to the relevant questions, we examined whether there were instances where the discourse of the principal was addressing issues that were related to Flexibility and adaptability. Then each instance was further categorized according to the component dimensions of Flexibility and adaptability (i.e., Critical thinking, Collaboration, Dealing with change, and Finding a middle ground among different opinions; see Table 3.1). A score of 0 or 1 was given for assessing each principal response, following the coding scheme presented in Table 3.4 (for the special case of the dimension Critical thinking of the skill Flexibility and adaptability).

Next, the scores in the component dimensions of Flexibility and adaptability were summed to derive an aggregate measure. Therefore, each principal had three scores for Flexibility and adaptability, i.e., one for each respective question. Once the grades for each principal on Flexibility and adaptability had been computed for questions 2, 3, and 4, Cronbach's alpha was calculated in order to obtain an indication of whether the questions were capturing the same construct. The same procedure was repeated for every 21CS, and the resulting Cronbach's alpha coefficients are presented in Table 3.5.

Table 3.4 Coding scheme for assessing the presence of Critical thinking in the instances of 21CS Flexibility and adaptability

Definition	Value	Example
This dimension was completely absent in the response	0	–
This dimension was mentioned in the response	1	"Innovative learning environments lead to better learning and each child has the opportunity to improve his/her abilities, to improve his/her critical thinking so as to feel secure and be able to adapt easily to the changes and innovative actions that we take at school" [Principal 13]

Table 3.5 Reliability coefficients for 21CS

21CS	Cronbach's alpha
Critical thinking, problem solving	0.819
Learning to learn, metacognition	0.562
Collaboration (teamwork)	0.587
Flexibility and adaptability	0.644
Communication	0.740
Creativity and innovation	0.526
Information and ICT literacy	0.684
Knowledge building	0.687
Social and cultural awareness	0.623

Using stringent psychometric standards, about half of the alpha values computed would be considered rather poor. However, given the small sample size, we consider the alpha coefficients as satisfactory indicators of the respective skill constructs. For each 21CS, we also calculated the average of each of the dimensions of that skill for the 15 participants of the study.

Considering the potential variability that could result from the various combinations, we used 10% as a cutoff value for determining whether a dimension was sufficiently present in principals' discourse or not. Thus, if a certain dimension of a particular skill was mentioned in less than 10% of the participants' answers in all the relevant questions, then we considered that it was not adequately represented in the data set.

Deriving a Measure of the Quality of ICT Use

One of the interview questions (Question 5) explicitly focused on the issue of ICT (see Appendix). The principals' responses to this question were scored using the following dimensions of ICT, adapted from Jonassen (2008):

- Technology as a tool to support knowledge construction
- Technology as an information vehicle for exploring knowledge to support learning by constructing

Table 3.6 Coding scheme for "Technology as social medium to support learning by conversing" in the "use of ICT"

Definition	Value	Example
This dimension was completely absent in the response	0	–
This dimension was mentioned in the response	1	"The introduction of ICT needs careful planning whether it is in the ICT lab or as visual aid in various subjects or as a tool for communication and dialogue among students, or even among teachers, so that ideas and opinions are exchanged" [Principal 13]

- Technology as an authentic context to support learning by doing
- Technology as a social medium to support learning by conversing
- Technology as an intellectual partner to support learning by reflecting

Binary coding was used for evaluating the principals' responses: a value of 1 when present in the principals' discourses and 0 otherwise. An excerpt of the coding scheme we used for scoring the dimension "Technology as social medium to support learning by conversing" is presented in Table 3.6. Once the scoring was complete, an overall score was obtained by summing the scores each principal received for the different dimensions.

Results

The first research question focused on how transformational principals view educational innovation and the underlying association between the two. First, the degree of transformational leadership conceptions of the principals is determined per se. Then principals' conceptions of educational innovations as reflected in their views on 21CS are described. Finally, the correlations between transformational leadership and views about educational innovations are presented.

Degree of Transformational Leadership

Table 3.7 presents the principal profiles in terms of perceived transformational dimensions as exhibited in their discourses.

Overall, the principals did not provide elaborate descriptions on any of the transformational leadership dimensions. Considering that they were exceptional leaders, we expected that they would primarily introduce aspects of their leadership that they think are more highly valued, i.e., setting a standard for other principals to follow. However, our results do not corroborate such an expectation. Some of the transformational dimensions are more evident in principals' discourses than others.

Table 3.7 *Descriptive statistics of transformational leadership* in descending order by mean score

Dimension of transformational leadership (*N* = 15)	Min	Max	Median	*M*[a]	SD[b]
Vision	0.25	0.75	0.25	0.33	0.15
Individual support	0	0.75	0.25	0.28	0.25
Intellectual stimulation	0	1.00	0.25	0.21	0.25
Common goals	0	0.75	0.25	0.21	0.21
Influential example	0	0.75	0	0.18	0.26
High expectations	0	0.50	0	0.06	0.15
Building common culture	0	0.25	0	0.01	0.06
Reward	0	0	0	0	0

[a]Mean
[b]Standard deviation

Table 3.8 Descriptive statistics of the 15 principals in transformational leadership

	Min	Max	Median	*M*[a]	SD[b]
Transformational leadership	0.50	3.50	1.25	1.30	*0.8*

[a]Mean
[b]Standard deviation

For instance, the mean scores for vision and individual support were the highest recorded, which suggests that the principals talked about the need for a vision and about supporting individual teachers more than about any other dimension of transformational leadership. On the other hand, dimensions such as high expectations (related to accountability), building a common culture (a more practical side of vision referring to the established practices), and reward have low mean scores. This indicates that reward schemes, culture building, and setting high goals, despite their importance, are the least talked about dimensions in principals' discourses. Finally, the three remaining dimensions fall in between these two extremes: intellectual stimulation, common goals, and influential example. The aggregate mean over all dimensions of transformational leadership is given in Table 3.8.

Since 8 is the maximum potential score that could be obtained with our coding procedure, the mean overall score of transformational leadership is rather low. Therefore, despite the fact that these principals were recommended by their peers and supervisors as being exemplary transformational principals, their combined mean score was relatively low. This finding indicates large potential for improvement, even for such an elite group of principals.

Educational Innovation

As a rule, none of the principals provided elaborate responses to any of the corresponding interview questions as far as the dimensions in Table 3.1 are concerned. However, it should be noted that only answers that actually included at least one of the relevant dimensions were counted as instances of presence of such a 21CS. Table 3.9 presents the scores for those dimensions of each 21CS that were adequately represented in principals' responses (i.e., more than 10% of the participants' responses mentioned the specific dimension or component skill). For each dimension the maximum possible score was 1.

A comparison between Tables 3.1 and 3.9 shows that only a minuscule part of all the dimensions present in each 21CS eventually find their way in the principals' discourses, Information and ICT literacy being the only exception in this trend (four of its dimensions are adequately represented). On the other side no dimension of Learning to Learn, metacognition finds its way to the table. Moreover and equally unexpectedly, the dimensions that are adequately represented are nearly always the same: use of ICT and collaboration. This means that in the vast majority of cases that a 21CS appears in the discourse of a principal, this is done through reference to the use of ICT or of collaboration as means to promote it, while no other parameter or prerequisite relevant to that skill is mentioned.

The data of the components for each 21CS in Table 3.9 was summed to create an aggregate measure per 21CS. Table 3.10 presents the aggregate scores of the 21CS in descending order.

The most frequently mentioned 21CS are (a) Information and ICT literacy, (b) Critical thinking, and (c) Communication. Most other dimensions are less represented

Table 3.9 Descriptive statistics for the dimensions of 21CS that were present in the principals' answers

21CS	Dimensions that were adequately represented in principals' answers	Min	Max	Median	*M*[a]	SD[b]
Critical thinking, problem solving	Collaboration	0	1	0.33	0.378	0.38
	Use of ICT	0	1	0	0.200	0.30
Learning to learn, metacognition						
Collaboration (teamwork)	Use of ICT	0	1	0	0.247	0.32
Flexibility and adaptability	Collaboration	0	1	0.33	0.333	0.31
Communication	Collaboration	0	1	0.33	0.33	0.3
	Use of ICT	0	0.67	0	0.22	0.27
Creativity and innovation	Use of ICT	0	1	0.33	0.29	0.35
Information and ICT literacy	Working in groups	0	0.67	0	0.22	0.27
	Evaluation of information	0	0.67	0	0.15	0.25
	Flexibility	0	0.67	0	0.13	0.22
	Innovation	0	0.33	0	0.11	0.16
Knowledge building	Collaboration	0	1	0	0.33	0.4
Social and cultural awareness	Collaboration	0	1	0.38	0.40	0.33

[a]Mean
[b]Standard deviation

Table 3.10 Ranking of the 21CS aggregate scores in descending order

21CS	Aggregate score
Information and ICT literacy	0.63
Critical thinking, problem solving	0.58
Communication	0.55
Social and cultural awareness	0.40
Knowledge building	0.33
Flexibility and adaptability	0.33
Creativity and innovation	0.29
Collaboration (teamwork)	0.25
Learning to learn, metacognition	0.00

in principals' discourses. Interestingly enough, Metacognition is notoriously absent in the administrators' discourses. It should be noted that although the principals of our sample mention Collaboration often as a means to achieve other goals, Collaboration as a 21CS has little prominence in their discourse.

Correlations

To determine the associations between transformational leadership and perceptions of educational innovation (as measured through conceptions of 21CS), we used the Spearman rank-order correlation coefficient as the distributions were neither normal nor were the relationships linear. The resulting correlation coefficients are given in Table 3.11.

With one exception, all correlations are medium to high, ranging from 0.4 to 0.6. The corresponding effect sizes for the magnitude of the association are substantial, ranging from medium to large. Of particular interest is the direction of the correlations, as they were all positive. In combination with the medium to large effect sizes, this suggests that the more transformational perceptions the principals voiced, the more innovative views they were likely to express on five out of nine dimensions of 21CS. The findings suggest that the higher the degree of transformational leadership, the more innovative views the principals hold. Finally, more than half of the coefficients turned out to be statistically significant, a finding that suggests a systematic relationship. More specifically, (a) Information and ICT literacy, (b) Critical thinking and problem solving, (c) Communication, (d) Knowledge building, and (e) Creativity and innovation turned out to be systematically correlated with the degree of transformational leadership. It is noteworthy that there was no correlation between transformational leadership and Metacognition and that the correlation with Flexibility and adaptability was low. Finally, it should be noted that running several significance tests increases the likelihood of type I error due to high chance capitalization. To address this, we attribute more importance to the sheer magnitude of the association of the correlation coefficients rather than to statistical significance per se. Thus, we treat significant correlations as having face value only and pay closer attention to the magnitude of the associations as reflected in the large effect sizes.

Table 3.11 Rank-order correlation coefficients between transformational leadership and 21CS

21CS	Transformational leadership	*p*
Information and ICT literacy	0.545[a]	0.036*
Critical thinking, problem solving	0.630	0.012*
Communication	0.522	0.046*
Social and cultural awareness	0.473	0.075
Knowledge building	0.582	0.023*
Flexibility and adaptability	0.434	0.106
Creativity and innovation	0.629	0.012*
Collaboration (teamwork)	0.500	0.058
Learning to learn, metacognition	0.086	0.762

[a]Spearman rho
*Correlation significant at the 0.05 level

The second research question inquired the associations between transformational leadership and perceptions of ICT use. It also focused on the relation between perceptions of educational innovation and perceptions of ICT use. To this end, the descriptive statistics for the dimensions of views about ICT use are first introduced, and then the associations between transformational leadership and educational innovations with perceptions of ICT use are presented.

ICT Use

Table 3.12 presents indices of central tendency and dispersion for each of the dimensions of ICT use. With one notable exception, all dimensions of ICT use are characterized by high mean scores. The role of discussion and dialogue in supporting learning seems to be the least represented aspect of ICT use in the discourses of the principals. However, it should be noted that, despite the relevant interview prompts, the study participants did not elaborate much on the different dimensions of ICT use.

The data in Table 3.12 were combined to produce an aggregate measure of ICT use. Table 3.13 presents the descriptive statistics for this measure. This grand mean is computed by averaging over all the means of the six dimensions of ICT in Table 3.12. As far as technology integration is concerned, the principals' grand mean score was quite high. Using this measure as a criterion, it can be concluded that the transformative principals' views of ICT integration in teaching and learning were very promising.

Associations Between Transformational Leadership and Educational Innovation with ICT Use

First, we examined whether the association between the variable transformational leadership and ICT use differed from zero using Spearman's rank-order correlation coefficient. The results indicate that the two variables were positively correlated at a statistically significant level (rho = 0.658, $p = 0.008$) and the effect size of the

Table 3.12 Descriptive statistics for the dimensions of ICT use

Dimension	Min	Max	Median	*M*[a]	SD[b]
Knowledge exploration	0	1	1	0.93	*0.26*
Support learning by reflecting	0	1	1	0.67	*0.49*
Authentic context to support learning by doing	0	1	1	0.60	*0.51*
Knowledge construction	0	1	1	0.53	*0.52*
Support learning by conversing	0	1	0	0.33	*0.49*

[a]Mean
[b]Standard deviation

Table 3.13 Descriptive statistics of the overall mean score of the 15 principals in ICT use

	Min	Max	Median	*M*[a]	SD[b]
ICT use	0	5	3	3.01	*1.6*

[a]Mean
[b]Standard deviation

Table 3.14 Correlations and probability values between perceptions of educational innovation and ICT use

21CS	ICT use	*p*
Information and ICT literacy	0.608[a]	0.016*
Critical thinking, problem solving	0.505	0.055
Communication	0.322	0.242
Social and cultural awareness	0.602	0.017*
Knowledge building	0.501	0.057
Flexibility and adaptability	0.171	0.543
Creativity and innovation	0.556	0.032*
Collaboration (teamwork)	0.199	0.477
Learning to learn, metacognition	0.053	0.851

[a]Spearman rho correlation coefficient
*Correlation significant at the 0.05 level

relationship is large. This finding suggests that the higher the presence of transformational leadership features in principals' discourses, the more likely were higher scores of ICT use.

Second, we determined the associations between perceptions of educational innovation and ICT use using the Spearman rank-order correlation coefficient. The coefficients obtained are given in Table 3.14.

The findings indicate that three 21CS (Information and ICT literacy, Social and cultural awareness, and Creativity and innovation) were systematically correlated with ICT use. The correlations were substantial, as the corresponding effect sizes were large (around 0.60). Finally, the direction of the correlation is positive, indicating that principals whose views were more innovative in these dimensions were also more likely to have high scores on ICT use. However, a very different picture emerges when we consider Metacognition, Flexibility and adaptability, and Collaboration. The results indicate that the principals of our sample do not exhibit high correlations between Learning how to learn, Fluent response to complex problems, and Goal-directed teamwork (collaboration) and ICT use. Finally, Critical thinking and Knowledge building are in between with correlations of medium strength.

Discussion

Transformational leadership has often been singled out as crucial for school improvement, innovation, and effectiveness (Evans, 1996; Hall & Hord, 2001; Hallinger & Heck, 1996; Pashiardis, 2013; Sarason, 1996). Additionally, its significance for integration of ICT in educational practices has also been reported (Ross et al., 2001; Weng & Tang, 2014). Therefore, long-standing concerns about both the frequency of ICT uptake in education (Cuban, 2013; Gray et al., 2010; Ward & Parr, 2010; Zhao & Frank, 2003) and the nature of this uptake (Cuban, 2013; Donnelly et al., 2011; Hayes, 2007; Hermans et al., 2008; Law & Chow, 2008; Li, 2007; Player-Koro, 2012) may, at least partially, be addressed by transformative principals who can promote ICT use (Ross et al., 2001; Weng & Tang, 2014). Since transformational leaders are—by definition—characterized by their awareness of the educational trends and their will and stamina for innovation, we would expect a match between transformational leadership and ICT-based innovation. The present study set out to explore how a group of administrators, who had been identified by their superiors as transformational, view educational innovation as a function of ICT.

The *first study objective* was to examine how transformational principals view educational innovation. The findings indicate high correlations between the degree of transformational leadership and the majority of 21CS we examined. This finding aligns well with expectations that transformational principals would be more open to educational innovation (Ross et al., 2001; Weng & Tang, 2014). In fact, the magnitude of the association was large for several dimensions of innovation, such as Creativity and innovation, Critical thinking and problem solving, Knowledge building, Information and ICT literacy, and Communication. Moreover, the pattern of associations is in the direction that would be expected from the literature (Ross et al., 2001; Weng & Tang, 2014). For instance, transformational leaders are the ones who search for innovative ways to achieve their goals and overcome the problems they encounter through critical and reflective analysis. Hence, their personal experience aligns well with the learning environments that 21CS promote. Furthermore, this finding is understandable when seen against the backdrop of popular public discourse in Greece. The most prominently advertised uses of technology in Greek public discourse center on critical thinking and creativity. Hence, it is logical that transformational leaders are heavily inclined toward appreciating Creativity and innovation and Critical thinking and problem solving (as the large effect sizes of the correlation coefficients suggest, rho >0.60).

The *second objective* of the study was to identify how transformational principals view educational innovation with respect to ICT use in teaching and learning.

The results indicate that the principals' views about ICT were quite high on the measures used, particularly for using ICT for (a) knowledge exploration and (b) learning reflection purposes. As expected, the relationship between transformational leadership and ICT use was positive: the higher the degree of transformational leadership views the principals held, the more positive views they expressed regarding the dimensions of ICT use. Moreover, the principals' perceptions of ICT use were positively related to educational innovation and in particular with (a) Information and ICT literacy, (b) Social and cultural awareness, and (c) Creativity. The magnitude of the correlations indicates that, for transformational principals, the aforementioned dimensions of 21CS are systematically associated with perceptions of ICT use. This pattern of associations is in line with the findings of preliminary studies on the topic (Ross et al., 2001; Weng & Tang, 2014), indicating that the higher the level of perceptions of Information and ICT literacy, the more positive views the principals expressed for ICT use. Seen in the local context, this finding is also expected. Public educational discourses about ICT use in Greece are typically replete with references to the importance of information access and exchange. They often emphasize the potential for information exchange between schools, school-community bridging, and reaching out to authorities and other experts. Such ICT affordances are generally considered to provide enriched learning opportunities for students because they entail authentic learning experiences.

Overall, our results are very *optimistic* with respect to transformational principals' views about technology-based innovation. Transformational leaders indeed hold views that are favorable to innovation and ICT use. Therefore, the present study contributes to the literature on the topic by (a) corroborating this relation with Greek transformational principals and (b) providing an elaborate pattern of associations between transformative leadership and ICT-based innovation. However, despite the positive picture that emerges, we think that the specific clustering of principals' perceptions warrants a closer examination.

First, we need to point out that *the degree of transformational leadership is limited*. As the results on transformational leadership indicate, although the principals in our sample were highly recommended by their supervisors as fitting a transformational profile, *their discourses actually show only a mediocre presence of transformational leadership dimensions*. This is further exacerbated by the near total absence of dimensions which we consider to be critical, such as (a) High expectations (i.e., accountability), (b) Building common culture (a more practical side of vision referring to the established practices), and (c) Rewards. Therefore, there appears to be a binary clustering of leadership dimensions: *some are highly popular among transformational principals, while others are not*. This split suggests that there is likely not much sensitivity to issues of institutional memory and schools as institutions that learn (Senge et al., 2000) among the transformational principals of our sample. More specifically, a vision requires a network that is coordinated around a set of common goals. This network is formed by high expectations so that each member of the school community does their part. A vision also requires a shared culture that facilitates communication about the vision, so that the vision is both understood and adapted to the actual conditions which may emerge in practice

(Hiatt-Michael, 2001). The fact that such aspects of transformational leadership are underrepresented in the principals' discourses resonates with how they downplay collaboration (teamwork) and metacognition when contemplating the learning environments that they see as valuable for students in their schools.

Second, the 21CS are unequally represented in the principals' discourses. For instance, while there is a large pool of component dimensions for each 21CS, *a specific pattern emerges from the study*. With the exception of the 21CS Information and ICT literacy, the only dimensions that get adequate representation in the principals' discourses of all the other 21CS are (a) Use of ICT (b) and Collaboration. Moreover, the 21CS Learning to learn is essentially absent in the principals' discourse. Other 21CS skills such as Flexibility and adaptability and Collaboration (as a goal per se) also have a very limited presence. Not only are they infrequently mentioned (see Table 3.10), but they also are characterized by medium correlations with transformative leadership (see Table 3.11) and small correlations with ICT use (see Table 3.14). Lastly, given the rich variety of uses of ICT mentioned by the transformational principals, one would also expect several strong associations between 21CS and ICT use.

Overall, both aforementioned points are characterized by a particular *clustering:* some transformational leadership dimensions and 21CS are more talked about by principals than others. This means that some transformational leadership dimensions and 21CS are prioritized over others, some are seen as less relevant, and finally some are completely ignored. Therefore, while positive about technology-based innovation, the *transformative principals mainly adopt a very specific conception of ICT-based innovation*. For example, take the lack of correlation between Metacognition and Flexibility and adaptability with Use of ICT which might suggest that the specific type of ICT use conceived by the principals does not include, e.g., tasks such as investigation of open problems and reflection on results and procedures. Furthermore, the lack of systematic correlations between Communication and Collaboration with ICT use might also suggest that the principals assign little significance to promoting dialogue through technology. Based on this observation, two questions are worth further exploration.

First, are such conceptualizations neutral in terms of their implications for practice? We need to examine what the specific flavor of 21CS the principals seem to favor entails for the types of practices that the principals can actively support in their schools. The fact that transformational leaders ignore specific 21CS might have important consequences for the types of learning environments that the principals value. Such value assignments are important because they might eventually affect the role technology could potentially play in actualizing learning environments. The specific image of technology-based innovation that the principals adopt is one in which technology may end up serving more of a *decorative function rather than a fundamental one.* This in turn might mean using technology to support existing educational practices rather than to subvert them.

Second, are such conceptualizations coincidental? We need to explore why even transformational principals prioritize certain dimensions of innovation over others. As we have argued in the past when discussing conceptions of ICT held by a small group of highly skilled teachers (Karasavvidis & Kollias, 2014), this ordering is probably due to the fact that *some innovative dimensions are alien to the grammar of Greek schooling* (Tyack & Tobin, 1994). To conceptualize such phenomena of *selective focus and resistance to innovation*, we have recently put forward the concept of zero-order barriers (ZOBs) (Karasavvidis & Kollias, 2017). As far as educational innovation is concerned, ZOBs represent the material conditions which essentially mold teachers' and principals' perceptions, giving them a specific form like the one we have documented in the present work. For example, the dominance of specific 21CS dimensions such as (a) use of ICT (b) and collaboration in principals' discourses can be understood if one pays close attention to the local Greek context. On the one hand, ICT has risen to prominence in Greece, and much of the official discourse turns to technology for ameliorating educational problems and improving learning. This prominence is reflected in building an extensive hardware infrastructure in schools, universal networking, massive teacher in-service training programs, new technology-centered curricula, and new textbooks to mention but a few. On the other hand, influenced by reform discourses, the constructivist mandate has put students into the spotlight, as they assume an active role in the learning process. The official constructivist dogma that has been actively promoted in Greece for over two decades has included student collaboration as an essential constituent of the "new learning." The switch from teacher-centered to student-centered learning has often been mainly interpreted as involving collaborative work. It would have been impossible for the average Greek teacher to miss out this overemphasis on technology and group work, much less for a transformational principal who is extremely sensitive to the latest educational trends. Consequently, the principals in our study appear to have internalized such discourses, prioritizing technology and collaborative work when discussing educational innovations. Against such a backdrop, the dominant Greek discourses on innovation of the past two decades are naturally echoed in their discourses.

As we have noted (Karasavvidis & Kollias, 2017), ZOBs represent latent factors that might not necessarily be directly observable in practice but are exerting a heavy influence on it. ZOBs constitute the web of contextual forces such as rules and legislation, historical traditions, curricula, and testing cultures. These forces regulate teachers' practices and shape their views and visions. Based on the clustering observed in the findings of this study, we conclude that ZOBs also apply to school principals. This conclusion is in line with the findings of other studies in the field of leadership. For instance, in a large study involving 46 principals and 2070 teachers in the USA, Goldring, Huff, May, and Camburn (2008) concluded that contextual factors such as students' socioeconomic status and school size account for the implementation of different leadership styles by the principals more than principals' personal variables. Similarly, Hallinger and Murphy (2013) reported that transformational leaders' intentions are hampered by factors such as the time available to lead learning and the normative environment of principalship. Such findings corroborate the conceptualization of ZOBs. Principals' perceptions are not formed in void: they are a function of the forces that operate in their work contexts. The clustering of principals' conceptions suggests that even transformational principals could reach a *plateau* in terms of ICT-based innovation. Therefore, we argue that the breadth and depth of innovation that transformative principals in Greece can conceptualize might be limited by ZOBs and reformers need to take the implication of this fact into serious consideration.

Conclusion

While on the surface transformational leadership appears to be a potentially significant contributor for promoting ICT-based innovation, the findings of the present study suggest that transformational principals per se might fall short of the expectation. The study findings indicate that they hold views that are favorable to innovation and ICT use. However, three findings indicate that even transformative principals' approach to educational innovation is selective. First, some leadership dimensions are absent in the principals' discourses which indicates an oversight of the school as a learning institution. Second, learning how to learn is virtually absent in the principals' discourse, while flexibility and adaptability and collaboration (as a goal per se) also have a very limited presence. This suggests a vision of optimal learning that is not in sync with the corresponding visions of the academic and research communities. Finally, while each 21CS presents rich detail expressed through various subdimensions, only two are by far the most dominant ones in the principals' discourses. This finding indicates appropriation of the dominant themes of Greek educational discourses on a surface level but does not necessarily reflect the deeper understanding that would be required should the principals be expected to actualized a 21CS-based innovation agenda. As it is difficult to attribute the specific clustering of conceptions observed in the study to principals' personal characteristics, we argue that educational reform stakeholders need to carefully examine how ZOBs define principals' practices, potentially either limiting or annulling technology-based innovations.

Appendix

Demographic Information Questionnaire

- Gender
- Age range
- # of years as educator
- # of years as principal
- Education (graduate and post graduate)
- Further training in educational issues
- Current number of teaching hours (principals in Greece teach a certain number of hours each week)

Interview Questions

1. How would you describe the effective principal?

   (The question could be further elaborated if needed.) What are the characteristics that you think that a principal should have in order to be effective? Can you give some examples to clarify your answer?
2. There are many proposals for innovative programs for the schools, and each one has some theory that supports it. When you assess the learning gains that such a program will bring to your students, what is it that you mainly look for? How do you decide whether there will be real learning gains for your students?

   (The question could be further elaborated if needed.) Can you give some specific examples of innovations that were realized and you are happy with them and of some others that were realized but you are unhappy about?
3. Principals often develop a common vision for the school that they lead. What is the vision in this school?

   (The question could be further elaborated if needed.) Have you managed to make it real or are there obstacles that have blocked the way?

   Let us suppose that a new teacher comes to the school. Perhaps she does not initially understand the vision of the school, especially that part that deals with the quality of student learning. What do you do, especially if she is a young teacher, so that she comes to accept the school's vision?
4. Have you ever experienced working in a classroom where your learning ideal has been realized? What are the characteristics (features) of this classroom?

   (Then the following question was asked.) Given your experience with leading the school and with teaching, what are for you the factors that lead to high-quality learning for students?
5. In recent years, ICT use has a central position in education. Do you think that the use of ICT is conductive to better learning? How do you use ICT in supporting learning?

   (They were also asked to give specific examples.)
6. What actions do you take in order to develop better ties with the teachers in the school, the parents, and the local community?

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Chapter 4
Addressing Creativity in the Collaborative Design of Digital Books for Environmental and Math Education

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Introduction

Creativity has been traditionally a popular theme and a challenging field for scholars from various disciplines to address. During several decades a wide array of approaches has been developed, each of them offering a variant interpretation of the construct (Cropley, 1999). Dominant among these approaches is the association of creativity with exceptional performances and groundbreaking ideas manifested by some few and very talented individuals ("Big-C" creativity) mostly in the fields of arts and culture. However, under newer paradigmatic frames, creativity-related work has considerably moved from the "individual genius" view, addressing creativity as an inherent capacity or an idiosyncratic trait, towards perspectives engaging more parameters and bringing the discussion to the role of pedagogy and education in fostering it (McWilliam & Dawson, 2008).

One such shift in the conceptualization of the construct is "little-c" or "everyday" creativity (Craft, 2000). This approach views the creative potential as being widespread among all individuals and displayed in various situations of everyday life. Manifestations of creativity are, for example, when a person realizes a new and improved way to approach an issue or accomplish a task or when someone comes to combine two previously disparate concepts or facts in a new relationship and perceive a situation in two habitually incompatible associative contexts. Processes of this kind can lead to the emergence of some new or "novel" understandings, ideas,

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or products that are meaningful at least to the person—without being necessarily historically new in a broader context (Kampylis, 2010; Sawyer, 2006). This perspective has fuelled liberal education-based efforts to boost the creative potential in all students as part of democratic, self-growth, and empowering learning experiences.

Another more recent tradition views creativity as a socially generated activity. There is growing evidence that creativity is part of a social capital or that it can be nurtured in collective experiences (Fernández-Cárdenas, 2008). These are thought as appropriate conditions to enhance what Moran (2010) calls “middle-c” creativity, involving the participation in dynamic processes of collaboration and co-construction among members of a group or small community. Entailing among others the negotiation of differing opinions and views and leading to more elaborated understandings of the issues at stake, collaborative work shares an inherent creative potential (Hämäläinen & Vähäsantanen, 2011).

Creativity has been also reckoned as a “situated” activity. It is not a uniform or neutral activity but acquires its meaning in reference to a particular context (social or cultural) and a disciplinary (knowledge) domain within which it occurs. Along this line of thought, creative teaching and learning cannot be viewed as an undifferentiated process across curricula. Instead, particularities of the subject matter and the teaching and learning environments in different knowledge fields need to come to the fore and with them the quest for appropriate modes, settings, and tools to enhance creativity in various educational practices. However, the inadequacy of most traditional educational systems definitely set various burdens in endeavours of this kind. Advances in theory have therefore to be coupled with more focused research, bringing forth structural changes in current educational processes, taking full advantage of the potential of information and communication technologies, and working towards materializing creative ideas into concrete, new, and more effective products and services with the engagement of all education stakeholders (EC, 2008; Ferrari, Cachia, & Punie, 2009).

In this paper we address creativity in the collaborative design of digital educational resources for environmental and math education. Emanating from a social approach and a situated perspective of creativity as taking place in a small community of educational designers, we explain the rationale that led us in the generation of a particular sociotechnical environment and a methodology for boosting creativity in the design of digital books, and we present a study focusing on the identification and analysis of the main phases of the joint work.

Creativity in the Collaborative Design of Digital Educational Resources

If we define “design” as the process to bring about new and previously nonexistent products (Coyne, 1995) or refined and improved versions of already existing products (Simon, 1996), then any design activity cannot but be inextricably connected with creativity (Taura & Nagai, 2010). A second dimension is that design is most often a collaborative endeavour involving more than one person in an exchange of ideas and shared work over prolonged periods of time. Any design activity can be therefore viewed as a socially based creative performance leading to the collaborative production of products, either tangible (artefacts) or intangible (ideas).

Instructional design and more particularly the "design of educational resources", although not overly acknowledged and studied as a mainstream design discipline (compared to other domains, such as software design or architecture), became the core concept of an emerging movement called the *learning design movement* (Laurillard, 2012). "Learning design" or "design for learning" is defined as "the practice of devising effective learning experiences aimed at achieving defined educational objectives in a given context" (Laurillard, 2012). There is also a need to nurture a culture in our 21st century education system, where teachers are encouraged to work collaboratively within their own communities of practice (but also with other educational design professionals) and with the aid of emerging technologies to creatively design effective and innovative teaching and learning processes and resources to promote educational quality and innovation along with professional development (Emin-Martínez et al., 2014).

In the context of the study presented here, we chose the theory of "social creativity" as an appropriate frame for describing and further exploring the creative performance of teachers in situations of collaborative design of digital educational resources. Its selection was primarily based on the fact that it is an approach that has been mainly conceived of in relation to the design practice (Fischer, 1999, 2000). Although it has not been employed so far in educational contexts, it offers an interesting perspective for addressing performance within diverse communities of designers who work together to attain creative solutions as a response to specific design problems.

The theory adheres that creativity can be fostered in "sociotechnical environments" (e.g. Fischer, 2001, 2005, 2011), i.e. communities of designers operating within purposefully designed technological milieus for supporting creativity. Fischer (2001) has put forth the idea of the "community of interest" (CoI) as a collective of practitioners from diverse disciplinary and professional domains "defined" by their shared interest in the framing and resolution of a problem (Fischer, 2004). The CoI's performance (the "social" component) is facilitated and/or boosted by being in close interaction with a "technical" environment designed to amplify the outcome of their collaborative efforts towards attaining specific goals (Fischer, 2005). Sociotechnical environments therefore function as "open systems" enabling and supporting the manifestation and synthesis of individual perspectives from diverse disciplinary and/or professional backgrounds into new ideas and artefacts (Fischer, 2011).

In the process such collaborative design efforts within a CoI, the diversity of the disciplinary and professional backgrounds of the designers sets various obstacles in their communication and collaboration. However, it is this very diversity that offers unique opportunities for the development of new shared knowledge. According to Akkerman and Bakker (2011), "socio-cultural differences that give rise to discontinuities in action and interaction" (p. 139) create "boundaries" which can be overcome by specific *boundary crossing processes*, i.e. mechanisms employed by individuals or groups to establish or restore continuity in their collaboration across practices. Social creativity can be viewed as enabled and nurtured by such boundary crossing encounters among the CoI members. Akkerman and Bakker (2011) identify four such boundary crossing mechanisms: (a) *identification,* through which boundaries are reconstructed without necessarily the overcoming the discontinuities, leading to a renewed sense-making of different practices; (b) *coordination*, entails processes such as communicative connection between diverse practices, leading to the overcoming of boundaries, facilitating effortless movement between different sites, etc.; (c) *reflection* on the differences between practices leading to an enrichment and new construction of identity; and (d) *transformation* leading to profound changes in practices and the emergence of new in-between practices.

We argue that "social creativity" provides an appropriate frame for addressing creativity in the collaborative design of digital books for environmental and math education. In the context of "Mathematical Creativity Squared" (MC2) project, within which research presented here has been conducted, we have built on this theoretical rationale to identify new environments and methods for boosting creativity in the collaborative designs of digital educational resources (Kynigos, 2015; Kynigos & Daskolia, 2014). This has been accomplished through (a) the development of a new genre of technological environment for the design of authorable e-books we called *c-books* ("c" for creative) and (b) the adoption of a methodology based on the generation of particular communities of educational designers with diverse disciplinary, epistemological and/or teaching backgrounds, brought together to design c-book resources responding to the following three design specifications: (a) to promote the creative mathematical learning and thinking of students by jointly advancing creative thinking and learning in relation to other disciplinary and educational domains, (b) to centre around the identification and investigation of real-life and real-world problems and (c) to interweave learning activities with narratives and widgets.

More particularly, the choice of jointly addressing math and environmental education in a series of c-books produced within the context of MC2 project was made on various criteria. Bridging math with other educational domains of a more socially oriented nature and with an orientation to real-life problems, such is the case of environmental education, has been suggested as a way to trigger meaningful and creative engagements with mathematical concepts in a wider range of students (Kynigos, Daskolia, & Smyrnaiou, 2013). Suggestions of this kind are further strengthened by criticisms to traditional paradigms focusing exclusively on abstract mathematical concepts and problems, promoting mainly foundationalist approaches of math teaching and learning in schools and reproducing the false myth of an objective and value-free discipline, alienated from current reality.

Besides, although many scholars have stressed the advantages of building a beneficial relationship between science and environmental education (e.g. Gough, 2002, 2007; Sjøberg & Schreiner, 2005, etc.), no relative bridging has been overtly proposed between math and environmental education for motivating students to get more actively involved with identifying the "mathematics" hidden inside some of the most pressing environmental and sustainability issues of our times. Nevertheless, dealing with such issues provides another potential for math education. By being nature ill-defined, complex, controversial, value-laden and by requiring the application of various perspectives to grasp them more thoroughly (Daskolia & Kynigos, 2012), they provide appropriate learning formats for triggering creative (mathematical) problem-posing and problem-solving (Torp & Sage, 2002). This can be further extended to the context of teachers' professional development by getting teachers engaged in dialogical forms of meaning-construction and perspective-sharing to expand the boundaries of their knowledge domain and to generate creativity. The study presented to be presented in the following sections is an example of such a professional development experience.

Social Creativity in the Design of the "Climate Change" C–Book

The Study Context

The study was conducted within the context of the European project "Mathematical Creativity Squared" (MC2, 2013–2016). It addresses "social creativity" as manifested in the collaborative design of a digital book (a c-book). A CoI of six members was involved in the task of designing the "Climate Change" c-book, a digital book interweaving sustainability concerns about climate change with mathematical concepts and thinking processes. The CoI designers were all Greek teachers with different disciplinary backgrounds and expertise in mathematics, mathematics education, environmental education, drama in education and the design of digital tools for math education. One of the members was assigned with the role of the moderator and was in charge for organizing the task and coordinating the design work.

The CoI's activity was located in the c-book environment, a technological infrastructure designed by the MC2 project to support designers in their task. It consists of two workspaces:

(a) "CoICode", a mindmap tool for organized asynchronous discussions with compulsory meta-data pertaining to the creativity aspects of the interaction process. CoICode also provides the designers with the possibility to rate any contribution against the criteria of "novelty", "appropriateness" and "usability" of the contribution on a yes/no basis. Based on this score, all generated ideas can be classified in terms of creativity, as well as in terms of their degree of perceived novelty, appropriateness and usability.

(b) The c-book “authoring tool” is environmentally designed to incorporate pages with dynamic and configurable widget instances accompanied by corresponding narratives. Designers/authors can write text, attach links, files or widget instances choosing from a set of available tools (e.G. MaLT, a 3D logo-based turtle geometry software, is a widget factory, and a microworld of this factory is a widget instance). This environment also includes a space where the students/users can interact with the c-book (the c-book player).

The task set to the CoI was to design a c-book that would foster creative learning in relation to math and environmental concepts in its prospective users (secondary school students) by inducing mathematical concepts and thinking processes in reference to identifying and/or analysing various dimensions of the climate change issue and by promoting the students’ active engagement and experimentation with them. The “climate change” c-book deploys the fictional story of a 12-year-old boy, George, inhabitant of an island located in the Pacific Ocean, who is forced to flee his homeland and become an “environmental refugee”. Soon he decides to get into a journey around the world and to set up a youth movement against climate change using social media. George comes across several facets of climate change and becomes aware of the causes (the greenhouse gases) and consequences of it (global warming, melting of the ice sheets, rise of the sea levels, etc.) and the impact of various human activities on raising the levels of carbon dioxide emissions.

As the story unfolds, several mathematical concepts “emerge” or have to be “identified” by the “readers” to facilitate the understanding of the various facets of the climate change issue. Students are prompted to experiment and tinker with widget instances to explore correlations between variables, estimate mathematical models, construct and interpret multiple representations, design 3D shapes, make and investigate assumptions, draw and extend conclusions related to climate change dimensions, etc. They are also challenged to establish connections between various representations of a concept (e.g. they are asked to depict and compare CO_2 emissions by drawing circles and disks) or to handle open problems (e.g. they use relevant information to estimate footprint values).

The “Climate Change” c-book comprises two sections: (a) “The Living Earth” section, focusing on the causes and effects of climate change (in 17 pages), and (b) “Making the Impossible Possible” section, addressing the human role in inducing and enhancing climate change and practical solutions to reduce its impact (in 8 pages). In total 18 widget instances were designed by the CoI members by making use of nine diverse widgets/widget factories and were incorporated in the c-book unit in close association with the deployment of the story.

The overall design process lasted for about 4 months (25/3/2015–21/07/2015). The CoI interaction evolved through 270 contributions posted in the CoICode workspace, 1 face-to-face kickoff meeting that took place during the first week of the design process and 87 e-mail exchanges, which were mainly initiated by the moderator and were meant to function as reminders and stimulate interaction whenever the flow of work was stagnated.

Methodological Approach and Research Design of the Study

For the purposes of the MC2 project, "social creativity" was operationally defined as "the generation of ideas and digital artefacts (widgets instances and the c-books), stemming from the combination of diverse knowledge systems and disciplinary domains, which result from the various boundary crossing interactions among CoI members and between them and the c-cook technology and are considered—at least by the CoI members—to be (1) novel, (2) appropriate and (3) usable to support creative mathematical thinking in their end users (students)". The project had a general goal to assess social creativity and better understand how it is manifested within the particular sociocultural environment (CoI + c-book technology). To this end a mixed research design was worked out, and a comprehensive measurement model was conceived. Different levels of analysis were applied to shed light to different facets of the design process as well as contribute to a more integrated understanding of social creativity.

In this paper we present and discuss findings from one level of analysis of the collaborative design work on the "Climate Change" c-book: this is related to the identification and mapping out of the workflow of the design process. The aim was to depict and understand the CoI's involvement in designing the c-book as an activity located in and boosted by the specific MC2 sociotechnical environment by identifying the various phases through which the overall design activity has passed through, starting from the moment the CoI converges in the CoICode workspace till the actual realization of the c-book.

The approach taken on this level of analysis was mainly qualitative and descriptive. The data used were the 270 contributions of the designers in the CoICode workspace from the outset of the design process till the final version of the c-book was released. They were in the form of CoICode extract transcripts in MS Excel form, which allowed adding some quantitative indicators for measuring interaction (e.g. number of posts per person, number of posts per period, averages, etc.). The transcripts were analysed line by line, and an open-substantive coding was performed as to the main processes, decisions and moves taken by the CoI members during the shared design work. To further illuminate the analysis representational data taken from the CoICode, analytic tools were used, depicting the progression of the CoI work over time.

Findings

Three stages in the CoI's collaborative design of the "Climate Change" c-book were identified out of the analysis of the data:

(a) The problem-framing and initial ideation stage.
(b) The c-book production stage, and.
(c) The fine-tuning stage.

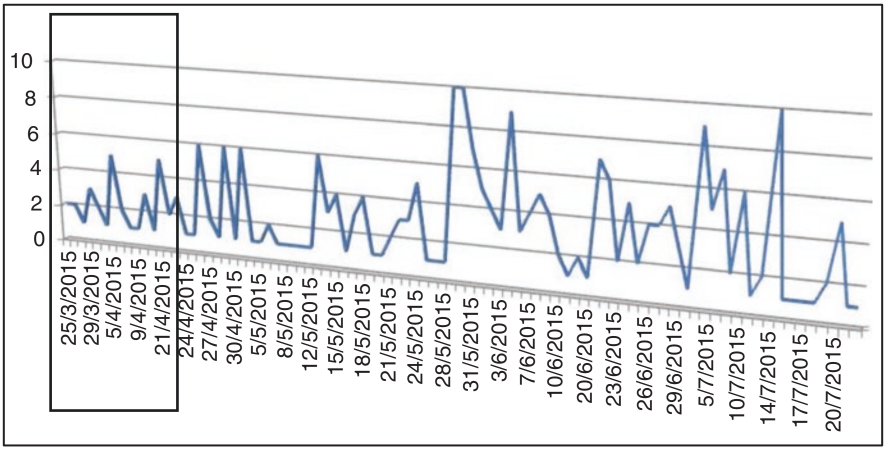

Fig. 4.1 Time distribution of posts during the first stage in relation to the total duration of the design process of the "Climate Change" c-book

The first stage (ideation stage) lasted for about 1 month (25/3–23/4/15). It is characterized by the CoI's joint efforts to frame the task at hand and develop their first idea pool. Within this period 31 contributions were posted by the designers in the CoICode workspace. The time distribution of the contributions made in this stage in proportion to the total duration of the design process is represented in Fig. 4.1.

The ideas articulated during this stage were organized in four CoICode trees (see Fig. 4.2). At the outset of the design process, the CoI members spent some time to approach the topic and the subject of the task and discussed about the structure of the c-book. The first tree of CoICode contributions (ten posts) was about framing the topic and the task, incorporating ideas in relation to the content and technology of the prospected c-book and supporting informative web-based resources about the issues of climate change (e.g. NASA, WWF, online lesson plans, etc.). The second CoICode tree (three posts) dealt with questions about how the c-book could be structured and the inclusion (or not) of problem-posing tasks. The respective ideas referred thus to the content and pedagogy of the c-book.

Gradually, the discussion became more focused and was oriented towards making decisions on the content (mathematical and environmental ideas), the didactical design (widget instances and corresponding learning activities) and the narrative. The interaction between the CoI members became more intense and incorporated the following categories of ideas:

1. Environmental ideas:
   (a) Causes of climate change: Greenhouse effect (greenhouse gases).
   (b) Effects and threats: Global warming, loss of sea ice, melting ice sheets, sea level rise, extreme weather events, drought/desertification, reduced agricultural yields, food shortage and health impacts.

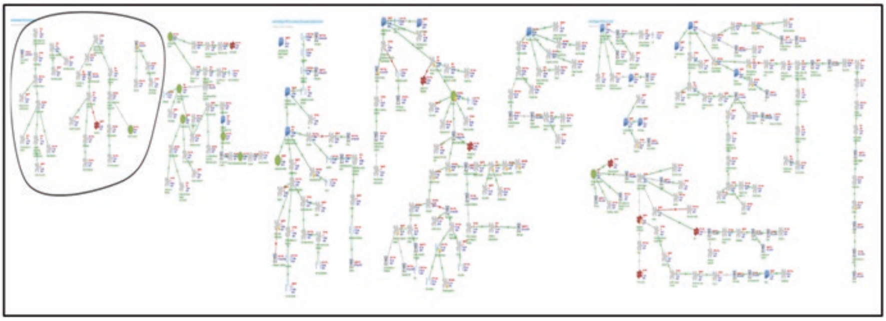

Fig. 4.2 First stage of the design process of the "Climate Change" c-book

   (c) Human activities: Fossil fuel industry, transportation, carbon footprint.
   (d) Solutions: Renewable resources, change of attitudes.

2. Mathematical ideas related to the didactical design:
   Statistics: Plotting the (linear) relationship between CO_2 and mean air temperature
3. Ideas about the design of widget instances:
   (a) GeoGebra: Plotting the relationship between CO_2 and earth temperature.
   (b) Online tool: Sea level rise.
4. Narrative ideas: End-of-the-world scenarios accompanied by comic strips.

A special feature of this stage is the CoI members' efforts to identify and coordinate various boundaries interplaying in the design process of the c-book, such as between math and environmental education or between primary and secondary education. The post that signifies the beginning of the third tree is articulated by a CoI designer with a math background who is asking CoI members with an environmental education background to help him get a good grasp of the issue of climate change. This tree (14 posts) incorporates two parallel discussion branches: (a) one about the age of the students the c-book should be addressing (considerations in terms of technology, content and pedagogy (6 posts)) and (b) one about the structure of the c-book (technology and content concerns (2 posts)) and the proposed widget instances to be designed (content and technology concerns (5 posts)).

Most of the CoI members who participated in the discussion about the students' target audience of the c-book suggested to be addressing secondary education because of the complexity of the relevant math concepts (statistics) and the difficulty in designing widgets for primary school students. A designer with a primary school teaching background objected to this idea a fact that postponed the decision to a later stage. What was nevertheless decided in this stage was that the c-book would be structured around three main themes: the "causes" and "effects" of and the "measures against" climate change. This decision was decisive in shaping the CoI's initial ideas about the widget instances to be developed.

The fourth CoICode tree (four posts) developed in this stage focused on the narrative of the c-book and contained technology as well as content and pedagogy considerations and suggestions. A CoI member proposed the idea of an "end-of-the-world" scenario accompanied by some comic strips, but this idea was rejected by other CoI members on both pedagogical (a more positive approach was argued to be more appropriate) and technical grounds.

The second stage in the "Climate Change" c-book design had a greater duration (22/4–8/6). With 134 contributions posted in CoIClode, this stage is characterized by the CoI members' dense interactions on issues about the didactical design and the narrative of the c-book while also focused on the technical implementation of former (suggested at the previous stage) and new ideas. In particular, ideas about the didactical design are intertwined with ideas about the narrative of the c-book. As a result, the produced widget instances at this stage have a decisive impact on the narrative, while at the same time, they are modified by the development of the story as the narrative unfolds (or as new ones are being produced). The time distribution of online contributions made in this stage in proportion to the total duration of the design process is represented in Fig. 4.3.

The ideas articulated during this stage were organized in five CoICode trees as follows (see Fig. 4.4):

1. Environmental ideas: Thermal expansion of water, changes in gravity due to ice melt, environmental racism.
2. Mathematical ideas related to the didactical design:

   (a) Statistics: Plotting the (linear) relationship between CO_2 and mean air temperature, modelling linear relationships, plotting CO_2 concentration (ice core records).
   (b) Calculating the volume of melting icebergs and sea level rise.

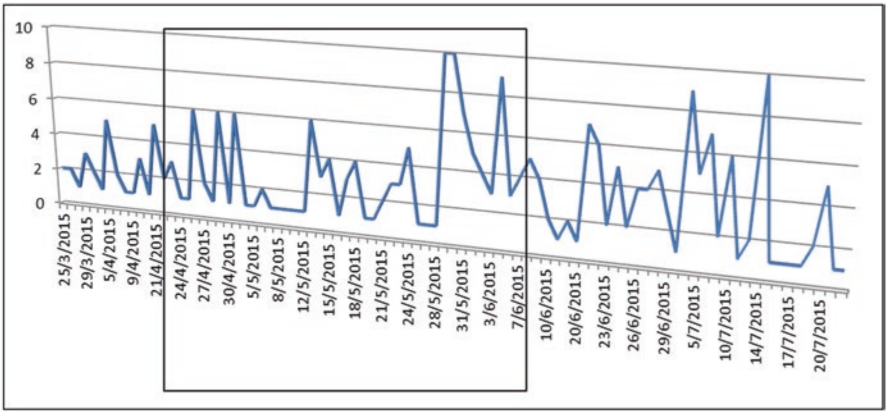

Fig. 4.3 Time distribution of posts during the second stage in relation to the total duration of the design process of the "Climate Change" c-book

Fig. 4.4 Second stage of the design process: C-book unit production

(c) Calculating and comparing CO_2 emissions (carbon footprint) and investigating the factors on which carbon footprint depends—Depict emissions by drawing circles.
(d) Representing visual information about temperature rise by graphs (multiple representations).
(e) Calculating energy consumption of a school building and designing solar panels (converting energy, orientation, tilt).
(f) Calculating the thermal expansion of water through the estimation of a suitable linear model and constructing a visual model of the water molecule.
(g) Relating Sea level rise to the loss of land in coastal regions.
(h) Learning about greenhouse gases.
(i) Investigating the role of ice melting in the sea level rise.

3. Ideas about the design of widget instances or specific widgets designed:

(a) A DME widget "statistical representation": Investigating the relationship between CO_2 and temperature.
(b) A GeoGebra widget: Plotting the relationship between CO_2 and temperature, plotting CO_2 emissions, modelling of thermal expansion, depicting emissions by drawing circles.
(c) Two DME widgets "Drawing in Space" and "algebra arrows": Calculating the volume of icebergs.
(d) A DME widget "graph tool": Representing visual information about temperature rise by graphs.
(e) A chronological ordering of glacier images.
(f) A Sus-X widget: A digital game about daily activities that influence the carbon footprint.
(g) A DME widget "Choice Answer Box": Learning about greenhouse gases, calculating and comparing CO_2 emissions.
(h) A DME widget "Text Answer Box": Writing down conjectures, conclusions and suggestions.
(i) An online tool: Relating sea level rise to the loss of land in coastal regions and calculating carbon footprint.
(j) Online carbon footprint calculators.

4. Narrative ideas:
   (a) The main character is a backpacker who travels around the world and keeps a diary in which she records her observations related to climate change.
   (b) George, a 12-year-old boy, inhabitant of a small island nation in the Pacific Ocean (Tuvalu), is forced to migrate because his homeland is threatened by the consequences of climate change (the rise of the sea level). He decides to travel around the world in order to gain knowledge and raise young people's awareness through social media about the phenomenon.

The second stage is the most extended in terms of duration and number of contributions. The beginning of this design phase is signified by a post referring to the upload of the first widget instance. Besides the design of widget instances, this stage is characterized by an intensive interaction about the narrative (technology, content and pedagogy) that took up a considerable part of exchange between the CoI members (42 posts). The participation of Sylvie, a primary school teacher specialized in drama education, who joined the CoICode workspace at that time together with Kostas' suggestions (an environmental education researcher), was critical in elaborating Rea's (also stemming from environmental education) initial idea about the backpacker.

Actually, the narrative of the c-book was a point of concern as early as in the first stage, but it was not until the c-book was halfway through its design process that it became a central preoccupation of the CoI. The discussion became more intense after some decisions were taken on the structure of the c-book and some of the widget instances had been already developed. Thus an original scenario that would incorporate the existing activities was needed. From then on, the intertwinement of the story deployment and the actual widget instances produced became a major concern of the CoI. As a consequence the c-book scenario was shaped as the following: *George, a 12-year-old boy, inhabitant of Tuvalu, an island nation located in the Pacific Ocean, is forced to migrate because his homeland is threatened by the consequences of climate change (the rise of the sea level). He decides to travel around the world in order to gain knowledge and raise people's awareness though social media about the phenomenon. George visits Venice (a city at risk due to sea level rise) and Athens (a city suffering from air pollution) where he meets his friends Roberto and Afroditi and becomes aware of several aspects of climate change: its causes (greenhouse gases) and effects (global warming, loss of sea ice, melting ice sheets, sea level rise and so on) and the impact of daily practices on CO_2 emissions (carbon footprint), therefore increasing human contribution but also their role in reducing the effects of climate change.* Shaping the scenario as such allowed several twists and turns to several directions so that several ideas related to the didactical design that were previously articulated in Stage 1 were now more easily incorporated into the narrative.

A new suggestion from Angeliki (a primary school teacher with a math education background) to design some widget instances for younger students together with its pedagogical rationale initiated a focused exchange of ideas about the feasibility of its implementation (six posts in a separate CoICode tree). The discussion seemed to have reached an impasse when a few weeks later, Dimitris (a secondary math teacher) designed an activity meant for younger students (quantifying qualitative data related to carbon footprint). However, the idea was abandoned as it didn't fit with the scenario or the rest of the anticipated activities. Despite the fact that it was not yet clearly stated, there was—from the beginning—a tacit assumption about the target audience of the c-book. It seems that the composition of a CoI had played a decisive role on influencing their orientation to the grade level the c-book was going to address (secondary school students).

The structure of the c-book and the organization of its content was also a topic of discussion in this stage. Eirini (a math educator) proposed an organization of the c-book into four sections: (1) *observing the climate change*, (2) *the greenhouse effect*, (3) *ice melting* and (4) *the human factor*. Later on, she added a new folder called "Scenario" and invited the CoI members to start building the c-book as one single section. In general, the CoI members opted for a continuous flow of the book: activities were incorporated in the narrative, and any formative text was inserted in pop-ups so that the reader is not overwhelmed and distracted by the large amount of text.

Another issue that came up in this stage as the c-book was evolving was its layout. Carefully selected videos instead of lengthy text, pictures, playful fonts and colours were thought to be highly engaging. Multimodality was also one of the designers' concerns.

Finally, during the third stage (the fine-tuning of the c-book), widget instances were further elaborated and finalized. This stage lasted for almost one and a half months (8/6–26/7) and contained 105 posts. As the c-book was eventually taking its final form, the designers focused their efforts on improving its coherence and appearance and on finding a narrative closure. The time distribution of online contributions made in this stage in proportion to the total duration of the design process is represented in Fig. 4.5.

This stage is characterized by a high degree of interaction. As the deadline for handing out the c-book was approaching, the moderator took up a decisive role in stimulating the interaction between CoI members by summarizing previously stated ideas and assigning specific tasks. Actually, the moderator initiated the discussion in three CoICode trees with a task management post (see Fig. 4.6).

Four new widget instances were produced as a result of the reification of ideas that had emerged during the second stage, using GeoGebra (plotting CO_2 emissions, modelling of thermal expansion, depicting emissions by drawing circles), while a new widget instance was designed by a CoI member using MaLT (constructing a visual model of the water molecule with logo commands).

Although fostering the students' math creativity was a major preoccupation penetrating the whole design process, this was the first occasion that it was explicitly discussed among CoI members. Divergent pedagogical considerations fuelled a vivid debate on the inclusion of open-ended activities. On the one hand, it was argued that creativity is stimulated by fuzzy activities, whereas on the other hand, it was stressed that activities should have a clear focus and rationale to provide sound learning opportunities. A compromise was reached when the developer of the

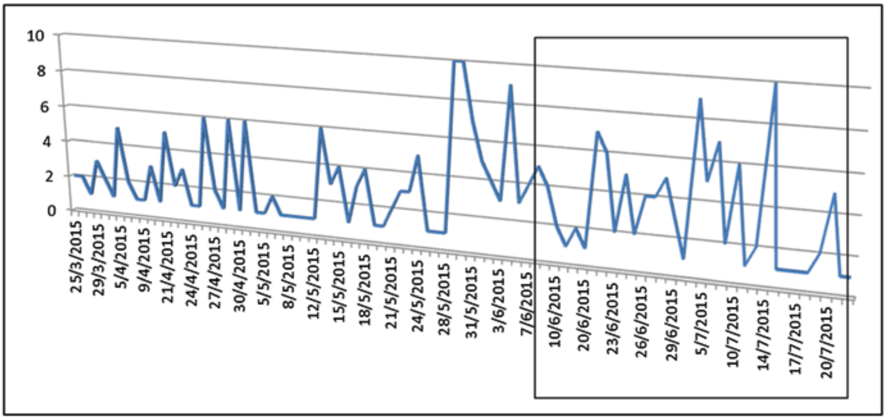

Fig. 4.5 Time distribution of posts during the third stage in relation to the total duration of the design process of the "Climate Change" c-book

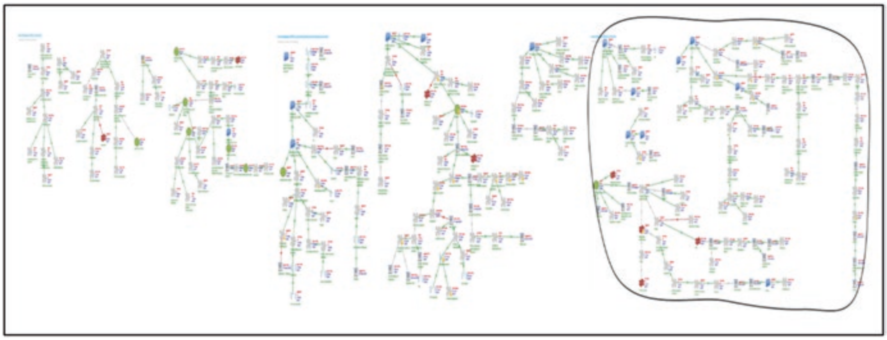

Fig. 4.6 Third stage of the design process: Fine-tuning

respective widget reduced the degree of complexity of the activity, which resulted in a more appropriate—for the specific target group—activity.

The narrative was still evolving as the CoI was searching for an appropriate ending, when an intense discussion broke out. On the one hand, the inclusion of a reflection activity was considered important on pedagogical grounds, while on the other hand, a less "realistic" ending would be in accordance with the style of the narrative and would boost the scenario. Finally, the CoI members reached an agreement, and both ideas were incorporated in the c-book. The ending is ambiguous, open to different interpretations and extensions of the story. It thus reflects the differences in perspectives among the CoI members and their concerted efforts to take all of them into account.

Discussion: Creativity in the Collaborative Design of the "Climate Change" C–Book

The study conducted within the context of MC2 project and presented here employed the theory of social creativity as a general framework to identify and study creativity in the collaborative design of digital books for environmental and math education. The analysis conducted addresses the creative process at the macro level, by focusing on the identification of the stages through which a CoI gets involved into a creative work that would finally lead to the production of some kind of creative product. The emphasis is placed on finding out which clusters of processes, decisions or moves (and in what sequence or rounds of iterations) lead to the implementation of the final outcome, the "Climate Change" c-book.

Three main stages of the design work were identified: (a) the problem-framing and initial ideation stage, (b) the c-book production stage and (c) the fine-tuning stage. Our findings are in accordance with several creative stage models that have been proposed describing the various phases through which a creative activity passes, when an individual or a team is confronted with a generative task to perform or a problem to solve. Most of them (i.e. Amabile, 1983; Osborn, 1963; Shneiderman, 2000; Wallas, 1926; Warr, 2007) converge on that every creative process involves an initial stage where the individual/team attempts to "define" the task or the problem and to "gather information" as to how to address it and what may be possible solutions to it (*problem-framing*). This is followed by an *idea-generation* stage where exploration and transformation of conceptual spaces occur (Boden, 1994) and the construction of outputs in the form of either ideas or more tangible products takes place. The final stage involves an *idea-evaluation* stage where the individual/team attempts to ensure, based on some own or external judgement, whether a new and useful product has been produced or whether a desired and appropriate solution has been attained. Sharing with others and getting a feedback on the outcome of the process (either an idea or the final product) may be also a critical point in the timeline of the evolution of the outcome, which can occur several times and may feed back into the creative process and inspire new or refined ideas and constructions to be generated in the pursuit of attaining the desired solution (Shneiderman, 2000; Warr, 2007).

Theoretical stage models can provide a useful frame for describing the evolution of a creative process as a whole. However, there are individual and contextual factors, which intervene and influence the creative process, which makes sense to focus our attention into investigating the creative process within particular "cases" and/or "situations" of creative work. One such case or situation is the one we addressed in our study. The analysis conducted gives us the opportunity to identify the boundary crossing mechanisms employed in the interactions among the CoI members and with the c-book technology while designing the "Climate Change" c-book. These were mainly those of identification, coordination, and reflection.

During the first stage of the design process, the CoI members attempted to frame the concept and issue of "climate change" bringing in the discussion their individual perspectives. They used identification mechanisms in order to define their field's interest and focus as well as to reconstruct their identity in light of others. In the second stage, the coordination of the two prevalent perspectives in the design of the c-book, i.e. the mathematics and the environmental education perspective as well as the processes of perspective-making and perspective-taking, resulted in the design of widget instances with a strong environmental aspect and made possible the infusion of creative elements in the narrative of the c-book unit. Coordination was also an important condition for establishing a communicative connection between the CoI members in terms of design suggestions and moves, revealing their efforts of translating them to each other's "language", so that dialogue is maintained and shared design work proceeds and develops.

Finally, reflection was employed in the second stage as, for example, when the CoI members got into perspective-making and perspective-taking to identify and build on the others' contributions and shared key resources or when they actually managed to collectively improve and turn an initial idea into a better elaborated idea or a new widget instance. Reflection was also a key mechanism in the third stage of the design process to fuel both the fine-tuning of the c-book in all aspects but also in the CoI members discussions about whether and how math creativity is promoted by the "Climate Change" c-book.

A second noteworthy point we can make based on our findings is that throughout the whole c-book design, the widget instances and the narrative co-evolved. This was a deliberate practice of the CoI as the interrelationship of widgets and narrative proved to be a major design preoccupation from the outset of the design process. The consecutive versions of the widget instances and the narrative were employed as boundary objects, not only in the sense that they facilitated communication and collaboration between CoI members but also in that they enabled perspective-making and perspective-taking which contributed to their transformation into new ideas and constructions. This finding led us to conclude that the collaborative versioning of diverse objects, the meshing of narrative with dynamic artefacts widgets and the interactions among CoI members, all allowed by the sociotechnical environment, eventually enhanced the designers' creativity.

Finally, the synthesis of the CoI had also a significant influence on boosting the creative potential of the design process. The CoI members took up very quickly their roles and responsibilities and were willing to reflect on each other's perspectives. As a result, a joint problem space was created and maintained throughout the design process. The diversity and complementarity of perspectives and identities fuelled several boundary crossing interactions that enabled the collective design of digital resources. Specific members often took a mediating role (boundary brokers) to help transcend the boundaries between the CoI and the technological environment when designing widget instances proposed by others. In general, the findings of our study suggest that both the sociotechnical environment within which design processes were situated and took place and the methodology employed enhanced the CoI designers' potential to generate a wealth of ideas most of which were rated as creative.

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Chapter 5
Creativity and ICT: Theoretical Approaches and Perspectives in School Education

Kleopatra Nikolopoulou

Introduction

Creativity in Education

Many years ago it was thought that creativity was a separate ability of specially gifted people, who were able to utilize this skill and be distinguished in different fields. Lately, psychologists (Craft, 2011) argue that creativity is not a special skill or ability of a few individuals, but rather it is the result of specific education and learning. Creativity can be regarded as not only a quality found in exceptional individuals but also as an essential life skill through which people can develop their potential to use their imagination, to express themselves, and to make original and valued choices in their lives.

Conceptually, "creativity" is defined as the capacity of producing a new project or an idea based on imagination (Cropley, 2001). A first attempt to define the concept was made by Guilford (1950, 1986): creativity covers the most typical capabilities of creative individuals that determine the probability for a person to express a creative behavior, which manifests itself via invention, synthesis, and planning. This behavior seems to be linked with certain personality characteristics, which have speculated whether and how this behavior will be expressed: creativity concerns all people, and it is not a rare phenomenon connected only to gifted people (the differentiation among people is quantitative and not qualitative). Getzels and Jackson (1962) define creativity as the combination of those elements which are considered original and different. They stress that creativity is one of the most valuable human capabilities, but its systematic examination is rather difficult. Lowenfeld and Brittain (1975) argue that creativity is directly related to the person that defines it. Thus,

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some psychologists distinguish as qualitative elements of creativity the flexibility of thinking, the originality of ideas, the ability to think differently, and the ability to solve problems. Piaget (1960) defines creativity as a process of problem-solving, problem finding, exploration, and experimentation, as a process that results in thoughtful decision making. Bruner (1962) defines creativity as an action which shows a distinct and effective surprise. Through the conceptual approach, it seems difficult to integrate creativity into one definition.

Lately, researchers (Beghetto & Kaufman, 2011) focus their attention on the creative potential/power available to each person and on the techniques that can activate this potential. They mainly focus on learning specific methods and techniques which can be used by all people in order to find many alternative and original ideas to their personal, social, and professional problems. The acquisition of knowledge and skills that promote inventiveness and people's readiness to utilize these methods in their daily lives are all considered useful. Their establishment in schools is also considered useful, in modern societies. Other researchers (see Henriksen, Mishra, & Mehta, 2015; Mishra, Henriksen, & the Deep-Play Research Group, 2013) provide a framework with three dimensions (novel, effective, and whole) for a "new" definition of creativity: creativity is seen as a process of developing something that is "new," a complex skill prevalent across domains and practices.

Regarding the importance of creativity in school education, Anastasiades (2017) highlights the collaborative creativity with the use of information and communications technologies (ICT), as one of the most important tools, which the thinking teacher has in order to respond critically to the demands of our times. His recent review reports on the characteristics of creative thinking such as the imagination, originality, and innovation, as well as on the development of divergent thinking, the development of new relationships, the pedagogical use of making an error/mistake, and the emotional climate. Important prerequisites for cultivating creativity in school education are the different ways of expression, in combination with the active participation of students in the construction of knowledge (e.g., formulating a problem is a more important process than problem-solving).

This work aims to investigate the link relationship between creativity and ICT tools (or digital tools) in school education. The structure of this chapter is as follows. Initially, it presents the theoretical views and empirical data regarding the potential of ICT tools in supporting creativity. Then, it discusses the essential role of teachers in supporting the development of creativity. Finally, it presents a small-scale study which investigated high school students' views as to whether ICT have helped or hindered their creativity. As a result of the theoretical discussion and empirical findings, the cultivation of creativity with ICT in schools can be appreciated. In this paper, the terms "ICT," "new technologies," and "digital technologies" are used synonymously. The use of the term ICT implies the broad range of information and communications technologies which can be used for different purposes by learners and teachers, in many situations.

Creativity and ICT in Education

Digital information and communications technologies (ICT) can be seen as a set of tools which can be chosen as and when they are appropriate in the creative process. Creativity can be promoted and extended with the use of new technologies where there is understanding of, and opportunities for, the variety of creative processes in which learners can engage. For example, claims are made for the expression of creativity in students and young people through the use of new technologies, from mobile phones to digital video and music (Sharp & Le Metais, 2000). Voogt and Pareja Roblin (2012) compared several (international) twenty-first-century frameworks and found that in almost all frameworks, communication, collaboration, digital literacy, problem-solving, creativity, and critical thinking were mentioned as important competencies for living and working in a digital society.

2009 was a year of creativity and innovation for Europe. The European Commission presented the results of the first survey on creativity and innovation in schools (European Commission, 2014–2015). The results showed that 94% of European teachers believe that creativity is a cornerstone skill that should be developed at school, while 88% are convinced that each of us can be creative. To make this a reality, 80% of teachers consider as important the ICT tools: computers, educational software, videos, online collaborative learning tools, virtual learning environments, interactive whiteboards, online free material, and online courses. Almost everyone believes that creativity can find a scope in every field of knowledge and school lesson, and it is not only related to those activities/lessons inherently creative such as arts, music, or theater. According to the survey, this approach is particularly important for the development of creativity as a multifaceted capacity, as it contains elements of curiosity, analysis, and imagination, together with the critical and strategic thinking.

The Potential of ICT Tools in Supporting Creativity

The use of the term ICT as a single term is inadequate to describe the range of technologies and the wide variety of settings and interventions in which they are used. McFarlane (2001) argues that there is a need for a more detailed and developed discourse to reflect the relationship between an ICT tool, the way in which it is used and any impact it may have on the users, from using word processors for writing letters to monitoring and measuring environmental changes with sensors. As there are different main factors (how students learn, the type and the use of ICT tools, the pedagogical approaches used, the design and implementation of curricula) that should be taken into account in the process of learning with ICT (Nikolopoulou, 2010), it is necessary to investigate the complexities of frameworks within which ICT tools are being used, without anticipating similar results for all students, in all cases. Indicatively, Anastasiades (2017) reports that, ICT, under appropriate pedagogical conditions, may be one of the most important tools for teachers and students to develop cognitive, social, and technological skills.

Loveless (2002, 2007) investigated the characteristics of digital technologies that allow students to be creative: interactivity, multiple types/forms of information, range, speed, and automatic functions, characteristics that allow users to do things that could not be done as effectively, or at all, by using other tools. For example, ICT tools enable users to make changes, to try out alternatives, and to keep the traces of the development of their ideas. Interactivity engages students-users at different levels, from playing games (which provide feedback to users' decisions) to monitoring-recording the results of an experiment (which again provide immediate and dynamic feedback). Additionally, the speed and automatic functions allow the ICT operations of storage, transformation, and display of information, so that students can engage in higher cognitive levels (e.g., interpretation, analysis, and synthesis of information). The recognition of the specific characteristics of digital technologies (ICT tools) allows students and teachers to decide when and how to use them. One of the key affordances of digital technologies is that content or knowledge can be created, shared, and discovered much more quickly and easily (Henriksen, Mishra, & Fisser, 2016). New technologies have much to offer to the world of creative sharing: for example, new applications for content development/creation, sharing videos/audio/images across global contexts, and websites that allow diverse creators to share content (such as YouTube). Taking into account the relevant literature (Cropley, 2001; Loveless, 2002, 2007; Mishra et al., 2013), Table 5.1 shows, indicatively, the specific characteristics of ICT tools and the basic features of creativity (elements of creative processes). It is noted that a single ICT characteristic may correspond to two or more elements of creative processes.

According to Table 5.1, knowledge of the specific characteristics/features of ICT tools (i.e., their dynamics in the educational process) can lead to informed choices about when using such tools, as well as to the evaluation of their use. It is the

Table 5.1 Specific characteristics of ICT tools and the basic features of creativity

Characteristics of ICT tools	Basic features of creativity (elements of creative processes)
Interactivity	Inventing
Multiple types of information	Desire for novelty
	Developing new ideas
Capacity	Using imagination
Range	Finding and solving problems
Speed	Linking apparently separate fields
Automatic functions	Being original
Electronic communication	Divergent and critical thinking
Distribution of information/materials	Autonomy and resilience
	Curiosity
	Effectiveness
	Analyzing and synthesizing skills

interaction between the distinctive features of ICT and the characteristics of creativity that opens up new perspectives for the development of creativity in education. Next section attempts to describe the interaction between features of ICT and the features of creativity, by using certain examples (on the basis of Table 5.1).

Examples of Creative Uses of ICT Tools

It is important to note that it is not the access to digital resources which delivers creativity but the opportunities such access affords for interaction, participation, and the active demonstration of imagination, production, purpose, originality, and value. Creative activities with new technologies can include developing ideas, making connections, creating and making, collaboration, communication, and evaluation (Loveless, 2002). Each of these activities draws upon an interaction between features of ICT and elements of creative processes (see Table 5.1). These activities are not always discrete or sequential, and there can be an overlap of applications. For example, the interactivity and capacity of ICT to represent information in a variety of modes underpins the potential of digital technologies to promote resources for imaginative play, exploration, trying out ideas, approaches to problem-solving, taking risks in a safe environment, and making connections between ideas. Software to support this includes simulations for modeling, spreadsheets, or control technology to sense, monitor, and measure and control sequences of events. The development of ideas and hypothesis testing can be performed by using simulation software in a history or a science lesson, where students are invited to explore "what will happen if …?" Students can use scanners, cameras, and graphics software to capture and manipulate images, create, and extract meanings in visual arts. Additionally, concept mapping software can support creative processes, such as brainstorming and representation of links among concepts. Digital technologies are changing what it means to create (Tillander, 2011). For example, students are using Google Earth as more than a map: they are shifting from a passive use of a tool to an active engagement, by constructing and designing virtual tools linking educational content.

Also, the use of ICT tools (e.g., interactive presentations) for the creation of multimodal texts with pictures, written text, animation, sound, and hyperlinks is a creative activity that enhances the imagination of students. ICT can play a role in making connections with other people, projects, information, and resources through the Internet. Knowledge is constructed through the interaction and communication with others in communities (Somekh, 2001). The speed and range of ICT tools provide opportunities for collaboration with others, directly and creatively. For example, the contribution of web2.0 is to encourage participatory culture by creating and sharing content in different social and cultural contexts (Anastasiades, 2017), while the use of group creative techniques (the groups work exclusively via the electronic environment) impact positively on production and processing of multiple alternatives, reinforcing the creativity of groups (Fesakis & Lappas, 2014). Another example is that programming environments allow students to detect and control events and processes to create their own applications in visual programming environments. Topali and Mikropoulos (2015) showed that those elementary school students who were involved in the process of creating simple educational games (programming in Scratch) were converted from ordinary users to authors, developing algorithmic thinking and constructing knowledge.

Creative uses of ICT can take place both in a specific (physical) space and time (e.g., the use of a computer or interactive whiteboard in the classroom) and also outside the classroom, in other than the school time (e.g., the use of mobile technologies or videoconferencing). The research field of human interaction with digital technologies with the aim to develop and promote creativity is in progress (Buckingham, 2013). As well as the physical spaces in which ICT resources are made available to promote learners' creativity, ICT applications themselves can provide environments for creative activity. For example, virtual reality environments and knowledge forums are spaces for potentially creative collaboration. Storyboard software has the potential to support students' engagement with and understanding of complex texts.

The Role of Teachers in Supporting the Development of Creativity in Classrooms

The integration of digital media and technology in school education is a priority of educational policy throughout Europe. It is now proven that for a well-designed ICT integration in education, it is not only new instruments and tools that are required but deep pedagogical changes through the school system itself and a more personalized approach to learning (Bocconi, Kampylis, & Punie, 2012). Mishra, Koehler, and Henriksen (2011) have argued that the best uses of educational technology must be grounded in a creative mindset that embraces openness for the new and intellectual risk taking and that this is a challenge for teachers. The researchers suggest that teachers must be creative in devising new ways of thinking about technology, particularly for teaching specific content. Ertmer, Ottenbreit-Leftwich, Sadikb, Sendurur, and Sendurur (2012) suggest building teaching dispositions that take advantage of the affordances of new tools for learning and thinking creatively, in ways not possible without new technologies.

Thus, the important role of teachers in the learning environments of the twenty-first century is highlighted. This role is directly related to teacher training and professional development and to the methods—activities for the development of creativity in schools. The following subsections briefly discuss these issues.

Teacher Training and Professional Development

In recent years, efforts are made in order to implement/cultivate creativity in school education, by establishing new organizational models such as the interdisciplinary model of learning and contemporary methodological frameworks. However, the new teaching materials and the modern methods are not enough, as it is required for teachers to receive appropriate training, to adopt innovations, and to introduce creative thinking in schools. As Paraskevopoulos (2004) mentioned, teacher training should aim at (a) the acquisition of knowledge about the nature, assessment, and cultivation of creative thinking, (b) practical training in specific techniques that will motivate creative thinking and will facilitate the production of creative ideas, and (c) teachers' change of attitudes, as well as the release of teachers' creative skills.

Loveless, Burton, and Turvey (2006) presented a theoretical framework for creativity and ICT, which can be used at the professional development of teachers. These researchers focused on the experiences of student teachers who designed, implemented, and evaluated creative activities as part of a school-based project. Their findings highlight the issue of designing appropriate learning experiences that promote and support creativity and ICT in the context of teacher education.

Teacher education students must have the opportunity to consider how creativity works in their own lives and practices, particularly with regard to technology and tools for teaching (Henriksen & Mishra, 2015). Recently, Henriksen, Hoelting, and the Deep-Play Research Group (2016) argued that teacher education and professional development are a step toward locating creativity within educational systems and suggested three key recommendations: (a) develop teacher education curriculum that integrates technology and creativity across the program, (b) specific courses/programs focusing on creativity and technology, and (c) identify or use a framework that connects creativity and technology to curriculum guidelines.

Teacher training is essential as it can assist teachers in acquiring relevant knowledge and skills in order, for example:

- To adopt methods that promote creativity and enable students to develop their creative thinking
- Not to provide ready solutions/answers to problems but to give students useful information which will serve as a source or tool to solve problems or generate ideas
- To use the potential and the affordances/assets of ICT tools
- To be flexible and adapt their methodological framework
- To utilize students' mistakes within the process of creative feedback and
- To be creative (themselves), by adopting creativity as an ability to create something new

Teachers' role in the process of supporting and developing creativity in classrooms is essential, and it is expected to have an impact on their students. Creative students, for example, may search for new ideas and solutions, may adopt new ideas and set high goals, as they may challenge the old and experiment with new situations.

Indicative Methods and Activities for the Development of Creativity in Schools

Teachers are those who will design the learning environments for the development of creativity in schools. Researchers report that such learning environments should provide opportunities for experimentation with materials, information, and ideas (Craft, 2000), opportunities for risk-taking in a creative environment, as well as opportunities for reflection and flexibility (Cropley, 2001). Additionally, the use of games and roles may enable students to develop their learning potential and to also develop their social skills (these are expected to help in generating ideas and solutions). Indicative methods and activities that can positively affect students' creativity in schools are proposed below:

- The creation of a "discovery" learning environment which will be open to new ideas.
- The method of brainstorming: this technique helps students to generate ideas, encourages reluctant students, and offers solutions.
- Focus on the process rather than on the solution.
- Focus on solution of problems that occur in everyday life, solutions based on the creative thinking of students.
- Dialogue and discussion: these are dynamic tools that allow students to express their views.
- Questions of open type, questions that may have many answers, as well as questions that stir students' imagination.
- Dramatization and role-playing (games).
- Construction/creation of objects by students.

ICT and creativity should be embedded in the school curriculum. Creativity is important across different disciplines; it is as important in science and mathematics as it is in the arts. In parallel, digital technology (ICT) has the potential to impact and change the creative processes. New technologies with their new affordances can stimulate and expand the way we think about creativity. A report published by the European Commission (Cachia, Ferrari, Ala-Mutka, & Punie, 2010) showed that around half of the teachers let their students use a wide range of technologies to learn (videos, cameras, educational software, etc.), while they prefer to stay in control of the technologies in the classroom. Allowing students to play with the tools can enhance students' motivation to think, understand, and learn in innovative ways. The process of integrating both technology and creativity into the curriculum is complex. However, the curricula documents should take into account the relevant issues so as to provide teachers with indicative activities for their lessons, as well as with examples of good practices.

A Small-Scale Study in a High School: Students' Views

Research Objectives

The objectives of the study were (1) to investigate students' views on whether the new technologies have helped or hindered their creativity and (2) to identify the keywords via which students describe the phrase "creativity with new technologies in school." It is noted that the small-scale study is distinct from the theoretical framework.

Sample, Questions, and Procedure

This small-scale study was conducted during 2 academic years, in an experimental high school in Piraeus, Greece, with students aged 14–15 years old. The participants of the pilot study (conducted in academic year 2015–2016) were 75 students, while at the beginning of the academic year 2016–2017, the participants were 81 students (i.e., a different sample, of 14–15-year-old students, who answered similar questions). All students have a computer at home. Regarding the first objective, students were asked to answer the question "how do you think the new technologies (ICT) have helped you, or hindered you, in being creative?" Regarding the second objective, they were asked to write down up to five words that come up to their mind when hearing the phrase "creativity with new technologies (at school)." Additionally, during the academic year 2016–2017, students were also asked to identify creative and noncreative activities. The short questions were answered anonymously and were given to their science teacher (author of this paper).

Results

Regarding the first objective, Table 5.2 shows the students' views as to whether ICT has helped or hindered their creativity. Most students answered that ICT has helped them in being creative, and more specifically they focused on information and the Internet (63 references), on school work (22 references), and on entertainment (17 references). Fewer responses were related to ICT as a barrier for their creativity (e.g., distraction, attachment to the screen) and to neutral views (ICT neither helped nor hindered me).

Some excerpts from students' responses are presented below. Regarding the contribution of ICT in being creative, they wrote:

> New technologies have not hindered me at all, in being creative. On the contrary, they gave me inspiration for my school work and daily information on various issues – they helped me enough.

Table 5.2 Students' views as to whether ICT has helped or hindered their creativity

Students' views	Number of references
ICT has helped my creativity	
Information, the Internet	63
School work/tasks, reading	22
Entertainment	17
Communication, socialization	11
New ideas	9
Mobile phones	5
ICT has prevented my creativity	
Diminishes my concentration, I stay on screen	11
I do not try	7
De-socialization	4
Neutral views (neither helped nor prevented my creativity)	9

> They helped me because through technology, I have access to art sites, and painting is my hobby. Additionally, I get to know people who live far away and I talk with them, broadening my horizons.

> The technology is useful to communicate with each other… the computer is useful in entertainment, songs, video, information.

> With new technology I got ideas and help, so that I can answer several questions.

As seen above, most answers focused on specific assets/possibilities of information and communication, broadly provided via the Internet. This was expected since the Internet is predominantly used by adolescents in comparison with other ICT tools or applications (e.g., simulations).

Regarding students' views on ICT as a barrier to their creativity, they wrote:

> Because of the technology, I think, we are *being carried away*, we waste our time

> the new technologies prevent us, they do not allow us in being creative.

> … ICT is an obstacle to our socialization.

> They prevent young people in being creative and in expressing freely themselves… behind the screen the adolescents hide their feelings.

Finally, a neutral answer was: "New technologies have neither helped me, nor blocked me in being creative. I am not particularly in favor of computers, but this does not mean I do not follow the evolution of the technology."

Regarding the second objective, students were asked to write down up to five keywords which come up in their mind, when they hear the phrase "creativity with ICT at school." Table 5.3 shows the most frequently written keywords. Most references (68) were related to the word "computers" or "activities on the computer."

Table 5.3 Frequently used keywords, written by the students when identifying the phrase "creativity with ICT at school"

Keywords	Number of references
Computers, activities on the computer	68
Internet	35
Collaboration in groups	30
Project	28
Interactive whiteboard	24
Entertainment, games	24
Creativity	19
Experiments	18
Projector	12
Information technology, programming	14
Communication	14
E-class	11

Other frequently mentioned words were the "Internet" (35 references), "collaboration in groups" (30 references), "interactive whiteboard" (24 references), and "entertainment/games" (24 references). From Table 5.3, it seems that some keywords reported by the students are similar to words/procedures that are linked to creative uses of ICT tools (as reported in literature). For example, references were made to the Internet, collaboration in groups, and programming. It is noted that these students have school experiences in the use of ICT in class (e.g., the Internet, interactive whiteboard, e-class), within different school subjects, as well as experiences of group collaboration and participation in projects (e.g., within the school or in collaborating with other schools). The words reported were also linked to their school experiences, a fact which highlights the essential role of the school in broadening students' experiences. The investigation of students' views is a first stage which can facilitate the design of a future large-scale study.

Those students who participated in the study during the academic year 2016–2017 were also asked to identify creative and noncreative activities with ICT. Creative activities were identified as the following: finding information on the web, listening to music or watching videos, communicating with others (e.g., via the social media), and some school activities (e.g., participating in e-twinning projects or in e-class). As noncreative activities they predominantly identified the online games (played on computer or on mobile phones), while a few students mentioned the social media. It is interesting that playing online games and participating in social media have been identified both as creative and noncreative activities. As one pupil put it: "e-class and school work with ICT are useful and creative, as well as is the entertainment. Since ICT facilitates communication, de-socialization happens only when someone loses the measure (i.e., uses this for a long period of time)."

Discussion

This paper attempted to explore the link between creativity and ICT tools in school education. Theoretical approaches and empirical data reveal the potential of ICT to support creativity. The small-scale study revealed that most pupils believe ICT has helped their creativity. The reasons for this, as well as the creative activities reported by many pupils (e.g., finding information and communicating via the Internet, collaboration with others, entertainment, projects), are within the spectrum of creative uses of ICT reported in the literature (Anastasiades, 2017; Loveless, 2002). The words used by pupils to describe "creativity with new technologies in school" were linked to their school experiences, a fact which strengthens the essential role of the school in enhancing pupils' learning experiences. Researchers (e.g., Mishra et al., 2011) highlighted the essential role of teachers in supporting the development of creativity in classrooms.

Limitations of the small-scale study include (1) how do students understand the phrase "creativity" and (2) how the role of ICT is being identified via the keywords shown in Table 5.3. For a future study, it is suggested to conduct a number of interviews with pupils, so as the qualitative data to complement the quantitative data. The small-scale case study was carried out in an experimental school in Greece. The policy of this school encourages teachers to undertake research initiatives, to try new methods, and to disseminate the findings. The findings of this study may have implications for this school's teachers. It is suggested for teachers to be aware of pupils' views, so as to motivate them to carry out innovative work and to cultivate creativity with ICT in school education.

Further research is needed in order to understand how creativity can be supported and developed through ICT in contemporary classrooms. Henriksen, Hoelting, et al. (2016) argue for a greater push for research to identify models and practices: there is a need for a more systematic research regarding the use of new technologies and their reciprocal relationship with creativity in education.

Taking into account that ICT applications change over time, and that creative processes may also change, some indicative questions for future research are: (a) what is gained and what is lost in experiences, in using ICT in creative practices? and (b) how are we using specific ICT tools (e.g., a paint program) to carry out activities we have done in the past by other means? Future research is useful to investigate the connections between disciplinary areas (arts, science, music, mathematics, literature, etc.) and creative ICT practices, as well as to develop approaches to creativity in contemporary classrooms.

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Chapter 6
Exploring the Potential of Computer-Based Concept Mapping Under Self- and Collaborative Mode Within Emerging Learning Environments

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Introduction

According to Novak (2010), a concept map (CM) is a (hierarchical) network comprised of concept terms (nodes) and directed lines linking pair of nodes; at the same time, CMs provide a window into students' mind, reflecting students' knowledge structures. Seen as an educational tool, the CM encourages students to organize and make explicit their knowledge. CMs are considered effective as teaching and learning tools that assist the development of conceptual knowledge, allowing visual observation of relationships and connections between multiple areas and pieces of information (Novak & Gowin, 1984). Moreover, the ability to recognize connections between different pieces of information or aspects of a problem facilitates problem-based learning (PBL) (Schaal, 2010). The latter assists the development of higher-order thinking skills, helping students to become independent, self-directed learners who appropriately respond to situations in a logical and reasonable manner (Savery & Duffy, 1995). Taking into account the previous approaches, a CM can be studied from different perspectives, for instance:

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- *The creator/s perspective*. The construction of a CM can be performed either in individual or in collaborative mode. Several studies have investigated the use/potential of CMs as supporting processes of self-knowledge management (Conceição, Desnoyers, & Baldor, 2008; Tergan, 2005; Tergan, Keller, Gräber, & Neumann, 2006; Vodovozov & Raud, 2015). Other authors, on the other hand, have explored the potential of collaborative CMs to facilitate knowledge construction as a study/collaborative tool (Gao, Thomson, & Shen, 2013; Koc, 2012; Lee, 2013; Lin, Wong, & Shao, 2012; Molinari, 2015; Rafaeli & Kent, 2015). Although originally developed to assist individual learners, collaborative use of CMs emphasizes brainstorming among group members, leading to visualization of new ideas and synthesis of unique concepts (Novak, 2010), requiring communication/negotiation processes, which guide learners to grow in their conceptual understanding (Kwon & Cifuentes, 2009).
- *The quality perspective*. The quality of a CM (QoCM) can be defined through quantitative/qualitative metrics in different spaces, e.g., on the basis of the correct propositions that it includes, and/or on the characteristics that concern its construct as a network or even its construction procedure. Upon the evaluation of such qualities, appropriate feedback could be provided. In general, the CM quality refers to the amount, depth, and breadth of information and the number of connections made among different items included in it (Gurupur, Jain, & Rudraraju, 2015).
- *The technology perspective*. Concept mapping has been described as a technique that can increase student's learning in the traditional classroom (Álvarez-Montero, Sáenz-Pérez, & Vaquero-Sánchez, 2015; Novak & Cañas, 2008). However, several studies have clearly demonstrated the efficacy of computer and/or online concept mapping tools/techniques in supporting the learning process (Kwon & Cifuentes, 2007; Omar, 2015).
- *The teaching-learning environment perspective*. The technological possibilities added flexibility that allows the integration of the CM in blended (b-) learning experiences (Adams Becker et al., 2017). These include face-to-face (F2F) and online modalities that are formed through the mediation of Information and Communications Technologies (ICTs), rather than being completely online or F2F (Michinov & Michinov, 2008). So far, limited efforts have been made to understand the development and use of theory in the particular domain of b-learning research (Drysdale, Graham, Spring, & Halverson, 2013; Graham, 2013). The concept of b-learning is embedded in the idea that learning is not just an episode but also a continuous/dynamic learning process. Blending different delivery modes/tools can be seen as an imaginative solution in educational contexts, since it has the potential to balance out and optimize the learning development (Dias, Diniz, & Hadjileontiadis, 2014). The computer-based learning environments (CBLEs) that can be integrated in b-learning assist individuals in learning, using multiple representations of information for a specific educational purpose (Ifenthaler, 2012). CBLEs frequently confront learners with a number of support devices (also referred as tools) in order to enhance learning, to help learners in their learning, and to provide a learning opportunity (Collazo, Elen,

& Clarebout, 2015; Garcia-Álvarez, Suárez Álvarez, & Quiroga García, 2014). However, according to Bates and Sangrà (2011): "Teachers must decide which tools are most likely to suit the particular teaching approach" (pp. 44–46).

This chapter seeks to explore the effects on the QoCM when shifting from individual to collaborative mode when the CM construction is embedded in the space of emerging learning environments.

Emerging Learning Environments

A variety of emerging approaches to education have been flourished nowadays, including competency-based assessment, open educational resources, flipped classroom, and micro credentials, combined with scholars' engagement in an ever-expanding array of emerging practices, such as blogging and/or networking on social media (Adams Becker et al., 2017; Veletsianos, 2016). In fact, technologies and practices are considered as emerging due to the environment in which they operate, also expressing inherent sociocultural aspects and co-producing capabilities (such as the Web-based online learning).

In the aforementioned vein, the option for a b-learning structure is justified by its flexibility, ease of access, and the possibility of integration of sophisticated and personalized technologies (Johnson, Adams Becker, Estrada, & Freeman, 2014). Moreover, collaborative (c-) learning puts collaboration as 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, enhancing the importance of affective (a-) learning.

So far, however, conventional teaching usually adopts the concepts of a-/b-/c-learning as independent learning pathways, neglecting the important interconnections and benefits that could be provided to both educators and 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.

From an emerging perspective, holistic approaches are needed to integrate 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 (see, e.g., the A/B/C-TEACH project[1]). In this vein, a novel way to apply existing educational theory is needed, so to bridge

[1] http://abcteach.fmh.ulisboa.pt/.

the areas of a-/b-/c-learning, creating a hybrid educational space that could support the traditional F2F, yet extended with an intelligent online learning part, centralized on b-learning and supported by a- and c-learning.

Using LMS Moodle data logger of a CBLE, built on the pedagogical strategies of behaviorism, cognitivism, constructivism, and connectivism, new metrics regarding the interaction (e.g., QoI) and collaboration (QoC) among users can be produced (Dias & Diniz, 2013). The latter could be combined with affective data (Petrantonakis & Hadjileontiadis, 2013) so to provide the estimated AS metric. Consequently, a personalized feedback could be resulted, initiating metacognitive processes, helping the educators/learners to become more aware of their interaction, collaboration, and affect. Hence, an "interactive/collaborative/affective mirror" could be built, in which the learners are encouraged to reflect upon how their interaction/collaboration behavior and affective state are improving their learning experiences. Moreover, enriched feedback regarding more global findings could be provided to the Higher Education Institutions' (HEI's) policy stakeholders, shifting from the existing LMS toward the iLMS.

The approaches regarding the CM construction that follow in this chapter stem from the aforementioned context and place the different CM perspectives within the holistic approach of a-/b-/c-learning.

Paradigms of Concept Mapping in Learning Environments

From the aforementioned it can be seen that the construction and study of a CM can be realized in various contexts that result from the affordances of the learning environments that is embedded in. This fact reveals a broad spectrum of possibilities that result from the combination of the CM study perspectives within the b-learning environment. Paradigms across the study perspective under consideration, e.g., in the technology perspective may include the estimation of the QoCM of a CM constructed through a paper-and-pencil approach in a F2F classroom situation or even more enhanced comparative research of the QoCMs between CMs constructed through paper-and-pencil and technological tools like IHCM CmapTools.[2]

In particular, the creator/s perspective has been empirically researched, either from the individual or from the collaborative mode of construction. Moreover, comparative analyses have been performed, investigating the possible merits of the shift from the individual to collaborative mode of a CM construction.

With regard to the use of CMs for educational purposes, five paradigms of research studies based on "individual mapping vs. collaborative mapping" are considered in the following subsections (sections "Paradigm 1, Paradigm 2, Paradigm 3, Paradigm 4, and Paradigm 5").

[2] http://cmap.ihmc.us/.

Paradigm 1

Kwon and Cifuentes (2007) aimed at investigating the comparative effects on science learning during the individually vs. collaboratively generated CMs on computers. More specifically, they wanted to determine the comparative effects on science learning of students (N = 74) from the eighth grade in a rural middle school in Texas. The science study essays were selected by the classroom teacher from the Prentice Hall Science textbook for eighth grade that was adopted by the school district. In particular, the science concept learning was selected as the dependent variable, and *pre* and *post* demonstrations by comprehension test scores were considered. The experimental setup foresaw three groups (i.e., the control group which was not trained in concept mapping and studied independently and two experimental that generated CMs on computers, individually and collaboratively, respectively, using the Inspiration software). Quantitative *post*-test scores were obtained through 40 computer-based multiple-choice items from the Prentice Hall test bank that was provided with the above eighth grade textbook and compared across the three treatment groups. The analysis revealed that individually generating CMs on computers are more effective on the basis of science learning than either independent, unguided study, or collaboratively generating CMs. Qualitative data were also obtained through questionnaire and video recording of classroom activities to describe the students' attitudes toward concept mapping and the study strategies that were employed across the groups. Students in both individual and collaborative concept mapping groups had positive attitudes toward concept mapping. Findings indicate that teachers should train their students in computer-based concept mapping and facilitate adoption of concept mapping as an independent study strategy.

Paradigm 2

Coutinho (2009) aimed at comparing the CMs that were constructed individually and collaboratively in a b-learning environment. The subjects of the empirical study were in-service teachers studying the curricular subject Research Methods in Education (RME) as part of a postgraduate teacher education program during the first semester of 2008–2009 academic year. In particular, the RME took place in a b-learning mode, throughout 15 weeks of 3 h per week, among which the construction of the CMs with the CmapTools software was used. The experimental setup foresaw two groups of teachers, the A with individual teachers and the B with small groups of 2/3 teachers, for the individual and collaborative construction of the CMs, respectively, upon the curricular subjects "sampling" and "methods for data collection." The total 38 maps (i.e., 22 from group A and 16 from group B) that were constructed were analyzed, quantitatively. More specifically, the elaboration of the analysis was performed upon the initial findings across the five dimensions proposed by Novak and Gowin (1984), namely, total number of concepts, total number of valid links, number of hierarchical levels, number of cross links, and number of examples. Unlike the findings of Kwon and Cifuentes (2007), the results have shown that the interaction in teams further helped the group in developing their understanding of the content under study. Moreover, the comparison of the CMs on a specific theme, designed by group B with those designed by group A, showed statistically significant difference. Finally, the scores, from the collaboratively constructed CMs compared to the individually constructed ones, indicated statistically significant improvement, showing greater understanding of the content and higher processing of related ideas as students pulled their knowledge together.

Paradigm 3

Kwon and Cifuentes (2009) performed a similar study (Kwon & Cifuentes, 2007), in order to investigate the comparative effects on science learning during the individually vs. collaboratively generated CMs on computers. The participants were 186 students in the seventh-grade science classes at a middle school. The experimental setup, as far as the performance of the three groups, was alike in the Kwon and Cifuentes (2007), yet with specific care on the groups' formation. The essays studied by the students were selected by the classroom teachers from the Texas Glencoe Science text for seventh grade. A comprehension test, consisted of 50 paper-and-pencil-based multiple-choice items, was selected from the teachers' manual for the Texas Glencoe Science text for seventh grade and was validated by both the teachers and researchers as appropriate for the study. Apart from the science concepts comprehension, the quality of both the individual and the collaborative CMs was also analyzed (alike Coutinho, 2009), on the basis of four dimensions proposed by Novak and Gowin (1984), namely, total number of valid links, number of hierarchical levels, number of cross links, and number of examples. Moreover, a learning strategy questionnaire and a computer survey were constructed and used as students' self-report instruments concerning their science learning strategy and attitude toward the CM construction experience. From the analysis of the experimental data, the control group performed less than both the experimental ones. In particular, concerning the effects of the construction of the CM either individually or collaboratively, the findings of this study also verified those of the Kwon and Cifuentes (2007), i.e., that the groups in the collaborative mode do not outperformed those in the individual mode as far as the science concept comprehension test performance is concerned. On the other hand, concerning the effects of individual vs. collaborative construction of the CMs, the results reported that constructing/sharing a CM with others requires communication/negotiation processes, guiding learners to grow in their conceptual understanding. Additionally, the collaborative process and the high level of social interaction resulted in more sophisticated CMs of higher QoCM. Most of the experimental students agreed that the computer-based CM tool was helpful for them to conceive the science concepts and generally adopt positive attitudes toward the learning approach.

Paradigm 4

Hwang, Shi, and Chu (2011) experimented in a CM approach toward developing mindtools for supporting collaborative ubiquitous (u-) learning activities. In total, 70 elementary school students of 10 years old participated in this study, and the learning task was to study biology concepts (i.e., butterfly ecology). They were aided by a Concept Map-Oriented Mindtool for Collaborative U-Learning (CMMCUL) that functioned either on personal computer or on mobile device mode and evoked the editing functions of the CmapTools (either locally or on the IHMC server via the Internet). The students were divided into three groups (i.e., the experimental group and the control groups—A and B). The experimental group created CMs individually using the CMMCUL in the classroom and then revised them upon the real-life observations in the butterfly garden using the mobile device and the collaborative mode of the CMMCUL. The control group A was asked to do the same, whereas during the garden observation, the construction of the CMs was to be done with a paper-and-pencil approach. Finally, the control group B did not construct any CMs (either prior or during the observation), but they used the conventional u-learning approach during their field study. *Pre*- and *post*-tests were used to quantitatively detect differences in the science learning outcome; questionnaire and interviews were also used to report qualitative findings. The results showed that collaborative CM construction achieves higher learning results. In particular, in the *post*-test results, the students who collaboratively constructed online CMs revealed significantly better learning achievement than the students who learned the same materials with other methods. Improved students' attitudes toward science learning, improved confidence in their peers, and higher expectations of collaborative learning were also reported. Moreover, the collaborative work encouraged students' engagement and self-efficacy in learning, as well as their motivation to communicate/collaborate with their peers.

Paradigm 5

Gaulão (2016), in an exploratory study, aimed at the realization of the way the use of the CM was perceived in the construction of the individual knowledge and in helping the collaborative work by 21 postgraduate students, taught entirely online. The students worked for a semester and were asked to construct CMs either individually or collaboratively. Empirical data upon the construction of the CMs were collected on the basis of a questionnaire. In particular, it referred to aspects related to the implications of the use of the CMs (i.e., closed questions) and aspects related to the individual and teamwork (i.e., open questions). The students expressed their strong agreement, among prepared statements presented to them, with those that referred particularly to the positive contribution of the CM experience in the construction, representation, and organization of knowledge. Moreover, concerning the design and construction of the CMs, the students considered the collaborative construction of the CMs as a more complex process than the individual one, requiring management of individual differences and setting aside the subjectivity that gives space to the complementary work.

A New Hybrid Approach

From the aforementioned paradigms, it is evident that the comparative benefits shifting from individual to collaborative construction of a CM were detected, indicatively, (a) at the content learning level, through *pre*- and *post*-tests, and (b) by estimating the QoCMs at the construct level, qualitatively through scoring structural components (e.g., according to Novak and Gowin (1984)) and qualitatively through questionnaire surveys and videos. The paradigms refer to subjects with ages from elementary school to adults. Additionally, the indicative examples manage to combine the *creator/s*, with the *quality* and the *technology* perspectives, yet without using elements of the learning environment perspective, as it is presented in the following hybrid approach that combines analysis of the QoCMs constructed individually vs. collaboratively in a b-learning environment that incorporates F2F and LMS supportive possibilities for the students.

The Analysis Framework

The analysis discussed here stems from the recent work proposed by the authors (Dias, Hadjileontiadou, Hadjileontiadis, & Diniz, 2017; Hadjileontiadou, Dias, Diniz, & Hadjileontiadis, 2016) and tackles the effects of the shifting from self- (SELF-) to collaborative (COLL-) mode, along with the use or not of the LMS Moodle, both upon the structural characteristics of CM and the peers' collaborative interactions within a CBLE. To quantify these effects, the following parameters are considered:

- CM-related: Topological Taxonomy Score (TaxScore)

In SELF-MODE, the $\text{TaxScore}_{\text{SELF-MODE}}$ ranges from 0 to 6, and it is calculated according to five criteria defined in Novak and Cañas (2006), i.e., (a) use of concepts rather than of chunks of text, (b) establishment of relationships between concepts, (c) degree of branching, (d) hierarchical depth, and (e) the presence of cross-links. Higher topological taxonomy scores typically indicate higher quality of CMs (Novak & Cañas, 2006).

In COLL-MODE, the difference of TaxScore is calculated, i.e., $\text{TaxScore}_{\text{Diff.}}$ The latter considers the difference between the topological taxonomy score of the collaboratively produced CM from the pair (S_i, S_j) and the lowest topological taxonomy score of the individually constructed CMs by S_i and S_j, expressing, thus, the maximum level of improvement in the topological taxonomy score when shifting from the SELF- to COLL-MODE. In particular, the $\text{TaxScore}_{\text{Diff}}$ is given by:

$$\text{TaxScore}_{\text{Diff}} = \text{TaxScore}_{\text{COLL-MODE}}^{(S_i,S_j)} - \min\left(\text{TaxScore}_{\text{SELF-MODE}}^{S_i}, \text{TaxScore}_{\text{SELF-MODE}}^{S_j}\right), \tag{6.1}$$

where $\text{TaxScore}_{\text{SELF-MODE}}^{S_i}$ and $\text{TaxScore}_{\text{SELF-MODE}}^{S_j}$ denote the topological taxonomy score of the CMs constructed by peers S_i and S_j under the SELF-MODE, respectively, whereas the $\text{TaxScore}_{\text{COLL-MODE}}^{(S_i,S_j)}$ denotes the topological taxonomy score of the CM constructed by the pair (S_i, S_j) under the COLL-MODE; min(•) denotes the minimum value, and indices *i and j* range from 1 to the maximum number of peers participated in each group of pairs.

- Peers' collaborative interaction: Turn-taking ($\text{TT}_{\text{COLL-MODE}}$)

Turn-taking refers only to COLL-MODE, i.e., $\text{TT}_{\text{COLL-MODE}}$, and is measured between the peers S_i and S_j across their collaboration during the construction of the collaboratively produced CM. The $\text{TT}_{\text{COLL-MODE}}$ takes into account all the alterations between the peers' active role (mouse control), when producing the CM.

- Peers' collaborative interaction: Absolute difference of the peers' balance (Bal_{Diff}).

Again, collaboration balance is considered in the COLL-MODE only and takes into account the number of {CON, REF, ORG} set contributions of each peer, normalized to the total number of the {CON, REF, ORG} set contributions in the pair. The {CON, REF, ORG} set includes CM-based structural elements, which relate with CM construction (CON), i.e., Add, Move, and Connect, expression of user's reflection (REF); i.e., Delete, Resize, and Modify; and CM organization (ORG), i.e., Concept, Linking Phrase. More specifically, the Bal_{Diff} is defined as:

$$\text{Bal}_{\text{Diff}} = \left|\text{Bal}^{S_i} - \text{Bal}^{S_j}\right|_{\text{COLL-MODE}} (\%), \tag{6.2}$$

where | • | denotes the absolute value and Bal corresponds to the peer's balance within the pair, defined as the number of {CON, REF, ORG} set contributions of each peer, normalized to the total number of the {CON, REF, ORG} set contributions in the pair, i.e.,

$$\text{Bal}^{S_i} = \frac{\text{card}\left(\{\text{CON, REF, ORG}\}^{S_i}\right)}{\text{card}\left(\{\text{CON, REF, ORG}\}^{(S_i,S_j)}\right)} \times 100(\%), \tag{6.2a}$$

$$\mathrm{Bal}^{S_j} = \frac{\mathrm{card}\left(\{\mathrm{CON, REF, ORG}\}^{S_j}\right)}{\mathrm{card}\left(\{\mathrm{CON, REF, ORG}\}^{(S_i,S_j)}\right)} \times 100(\%), \tag{6.2b}$$

where card denotes the cardinality of the {CON, REF, ORG} set contributions.

- LMS Moodle-related: Quality of interaction (QoI)

Moodle interactions allowed as in the 14 basic categories (C1–C14), namely (Dias & Diniz, 2013), C1, {Journal/Wiki/Blog/Form (J/W/B/F)}; C2, {Forum/Discussion/Chat (F/D/C)}; C3, {Submission/Report/Quiz/Feedback (S/R/Q/F)}; C4, {Course Page (CP)}; C5, {Module (M)}; C6, {Post/Activity (P/A)}; C7, {Resource/Assignment (R/A)}; C8, {Label (L)}; C9, {Upload (UP)}; C10, {Update (U)}; C11, {Assign (A)}; C12, {Edit/Delete (E/D)}; C13, {Time Period (TP)}; and C14, {Engagement Time (ET)}. These are used as inputs to the FuzzyQoI model (Dias & Diniz, 2013), to output the LMS Moodle user's QoI.

Experimental Implementation

One hundred and twenty-eight preservice vocational education teachers undertaking a 1-year pedagogical training program completed voluntarily the entire study. The participants were of age 28 ± 2.7 years., all Greeks and graduates from Greek universities. To avoid the potential extraneous factors of vocational specialty and gender in the experiment, the participants were paired upon their random listing within sex clusters to form the groups G1 and G2, of 64 students (32 pairs) each. All of them had experience in diagrammatic depictions (without linking phrases), yet none of them was experienced in CM construction and in using CM-related software (such as the CmapTools, either in SELF-or in COLL-mode), and Moodle LMS. Moreover, none of them had any experience concerning computer-mediated collaboration. The study lasted 6 weeks (W1–W6), in the second semester, and both groups performed CM in both modes, i.e., SELF-MODE (W1–W3) and COLL-MODE (W4–W6), yet G2 only was instructed to additionally use LMS Moodle during the whole period (W1–W6). Upon a written essay at the beginning of the second semester, the background of the participants was considered homogenous in relation to the text that was given to them, in order to transcribe it to CM in SELF- and COLL-MODE. The same researcher (the first author) performed the training and the experimental procedures. The implementation took place on the basis of:

- The use of the CmapTools that allows other users and oneself access to the constructed CMs from anywhere/anytime, allowing to work in pair or teams on them (Hanewald & Ifenthaler, 2014). Moreover, upon the feature of the CmapTools software to record/replay the construction procedure of the CM in both modes (i.e., SELF- and COLL-MODE), a .Txt log file is produced that extracts all the time- stamped interactions that were performed by its author/s, i.e., the {CON, REF, ORG} set of contributions. All the adult participants agreed not to use any extra reading apart from the given one for the construction of the CM.

- The LMS Moodle that was prepared from the beginning to provide its users' spaces for interaction that could trigger metrics in all the aforementioned 14 basic categories (C1–C14) for the measurement of the QoI via the FuzzyQoI model (Dias & Diniz, 2013). Moreover, the given text was uploaded to the LMS Moodle for the participants of the G2 (e-mailed to the participants of the G1), who agreed to use only the LMS Moodle as supporting tool.
- The F2F weekly communication, where clarifications were provided by the researcher to both G1 and G2 for the use of the CmapTool and only to the G2 for the use of the LMS Moodle.

Data acquired from CmapTools software and LMS Moodle use set the experimental corpus. The Cmapanalysis (Cañas, Bunch, Novak, & Reiska, 2013) plugin was used for the estimation of the taxonomy score; for the between-subjects (G1 vs. G2), statistical analysis, the one-way analysis of variance (ANOVA test), was employed, whereas for the within-subjects (SELF-MODE vs. COLL-MODE) statistical analysis, the two-sided Wilcoxon rank sum test was used, both implemented in Matlab 2016a (The Mathworks, Inc., Natick, USA).

Findings

In Fig. 6.1, the values of the outputted parameters from the experimental implementation are presented. More specifically, Fig. 6.1a, b presents the estimated $\text{TaxScore}_{\text{SELF-MODE}}^{\text{G1,G2}}$ values across all students per group and $\text{TaxScore}_{\text{Diff}}$ values across the pairs of both G1 and G2 groups, i.e., $\text{TaxScore}_{\text{Diff}}^{\text{G1,G2}}$, calculated via (1), respectively. Clearly, in this case, the shift from SELF- to COLL-MODE had a positive effect in the quality of the constructed CMs, as reflected in the increase of the topological taxonomy scores in both G1 and G2 groups, complying with the findings of (Kwon & Cifuentes, 2009). Moreover, for the case of G1 (Fig. 6.1b-blackface circles), the shifting from SELF- to COLL-MODE has produced, in general, positive $\text{TaxScore}_{\text{Diff}}^{\text{G1}}$ values yet with some negative ones (6 out 32) and some equal to 0 (8 out of 32). The $\text{TaxScore}_{\text{Diff}}^{\text{G2}}$ values (Fig. 6.1b-whiteface circles), however, are all positive and all ≥2, showing the beneficial effect of the LMS use in the quality of the collaboratively constructed CMs. From the SELF-MODE perspective (Fig. 6.1a), there is a similar behavior in the resulted $\text{TaxScore}_{\text{SELF-MODE}}$ values between the G1 and G2 groups, showing that LMS Moodle use did not affect the quality of the CM construction reflected in the relevant topological taxonomy score under this mode. A statistically significant difference was found between the $\text{TaxScore}_{\text{Diff}}^{\text{G1}}$ and $\text{TaxScore}_{\text{Diff}}^{\text{G2}}$ ($p = 4 \times 10^{-9}$), but not a significant one between the $\text{TaxScore}_{\text{SELF-MODE}}^{\text{G1}}$ and $\text{TaxScore}_{\text{SELF-MODE}}^{\text{G2}}$ ($p = 0.3398$).

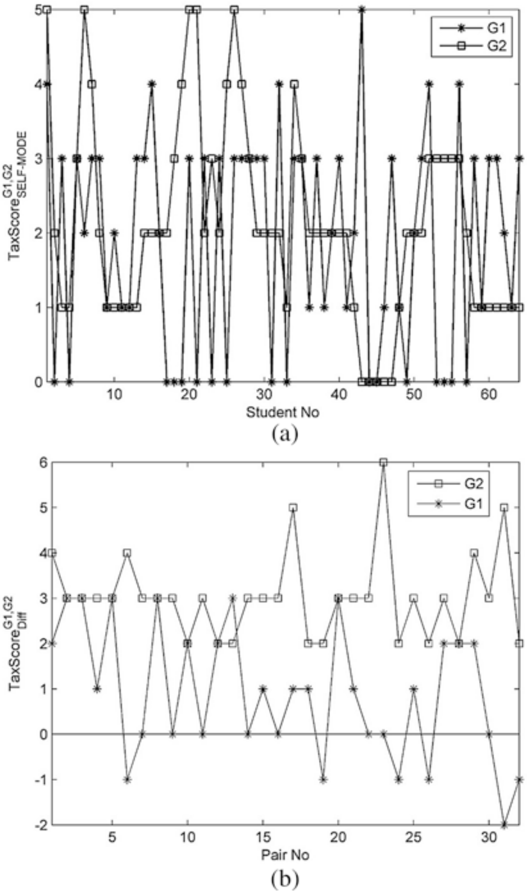
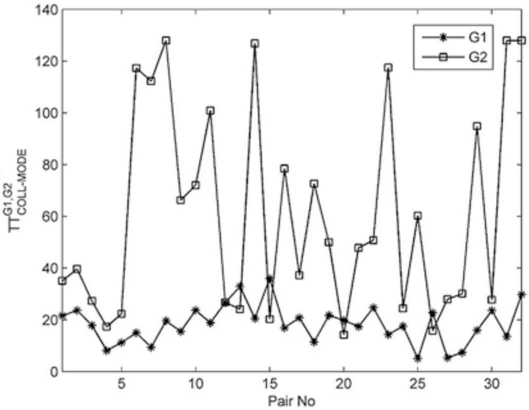
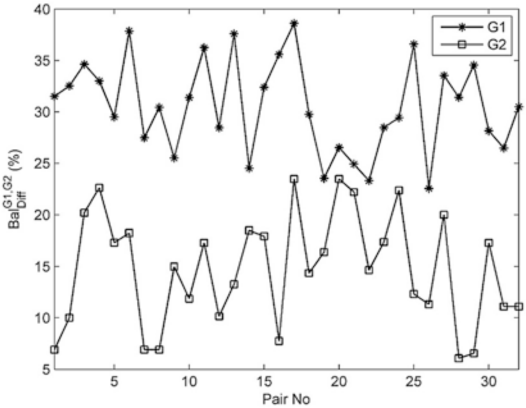


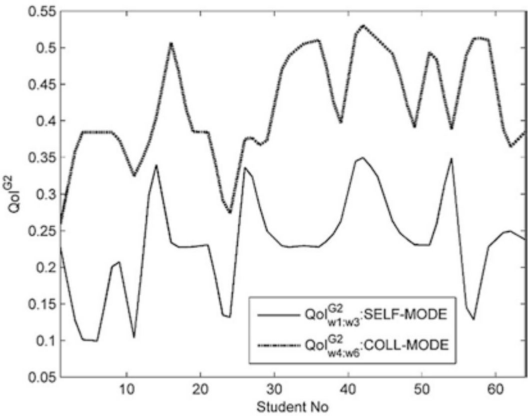
Fig. 6.1 (**a**) The estimated $TaxScore^{G1,G2}_{SELF\text{-}MODE}$ values across all students per group; (**b**) the $TaxScore_{Diff}$ values across the pairs of both G1 and G2 groups, i.e., $TaxScore^{G1,G2}_{Diff}$; (**c**) the $TT_{COLL\text{-}MODE}$ values across the pairs of both G1 and G2 groups, i.e., $TT^{G1,G2}_{COLL\text{-}MODE}$; (**d**) the Bal_{Diff} values across the pairs of both G1 and G2 groups, i.e., $Bal^{G1,G2}_{Diff}$; and (**e**) the estimated mean QoI when shifting from SELF-, i.e., $QoI^{G2}_{W1:W3}$, to COLL-MODE, i.e., $QoI^{G2}_{W4:W6}$, for each student of G2 group (Dias, Hadjileontiadou, et al., 2017; Hadjileontiadou et al., 2016)



(c)



(d)



(e)

Fig. 6.1 (Continued)

In Fig. 6.1c, the $TT_{COLL\text{-}MODE}$ values across the pairs of each group, i.e., $TT^{G1,G2}_{COLL\text{-}MODE}$, were estimated and illustrated for the COLL-MODE in both G1 and G2 groups. In almost all cases (exception of 4 pairs out of 32), the $TT^{G2}_{COLL\text{-}MODE}$ values were greater than the $TT^{G1}_{COLL\text{-}MODE}$ ones, exhibiting a mean value of $TT^{G2}_{COLL\text{-}MODE}$ almost three times higher than the one of the $TT^{G1}_{COLL\text{-}MODE}$. This difference was also statistically justified, as a statistically significant difference between $TT^{G1}_{COLL\text{-}MODE}$ and $TT^{G2}_{COLL\text{-}MODE}$ values was found ($p = 1.79 \times 10^{-7}$). This implies that the employment of the LMS Moodle use triggered further both G2 peers to participate in the collaborative activities during the collaborative construction of the CM.

Furthermore, in Fig. 6.1d, the Bal_{Diff} values, estimated via (2), across the pairs of both G1 and G2 groups, i.e., $Bal^{G1,G2}_{Diff}$, are illustrated. From the latter, it is evident that the pairs of G2 group exhibited more balanced collaboration compared to the ones from G1 group, as the Bal^{G2}_{Diff} values are always less than the Bal^{G1}_{Diff} ones, lying at a mean value around 15%, in contrast to the mean value of Bal^{G1}_{Diff} that lies around 30%. This was also statistically justified, as a statistically significant difference between Bal^{G1}_{Diff} and Bal^{G2}_{Diff} was found ($p = 9.5 \times 10^{-19}$). These results support the perspective that the LMS Moodle use potentially contributes to the avoidance of any possible domination of one peer to another within the pair, in terms of more balanced collaboration during the collaborative construction of the CM.

Finally, Fig. 6.1e depicts the estimated mean QoI when shifting from SELF-, i.e., $QoI^{G2}_{W1:W3}$, to COLL-MODE, i.e., $QoI^{G2}_{W4:W6}$, for each student of G2 group. As it is clear from Fig. 6.1e, there is a distinct improvement in the QoI when the students of G2 started their collaboration for the construction of CMs, as in all cases, $QoI^{G2}_{W4:W6} > QoI^{G2}_{W1:W3}$. This is further justified by the statistical analysis results, where a statistically significant difference between the $QoI^{G2}_{W1:W3}$ and $QoI^{G2}_{W4:W6}$ was found ($p = 4.54 \times 10^{-21}$). These results indicate that shifting from the SELF- to COLL-MODE had a positive effect in the corresponding student's QoI, motivating them to further interact with the LMS Moodle, responding to the demands of the collaborative activity during the COLL-MODE of the constructed CMs.

Overall, this approach (Dias, Hadjileontiadou, et al., 2017), when placed within the panorama of the works that combine hybrid perspectives in educational contexts, fills a gap that relates to the way the users interact with LMS and collaborate with CMs within a b-/c-learning context. When compared with the previous paradigms, the findings here comply with the works of Coutinho (2009), Hwang et al. (2011), and Kwon and Cifuentes (2009), fostering the positive effect of shifting from SELF- to COLL-MODE in the CM construction. Nevertheless, none of these works extend the vision of combining the CM with the LMS Moodle use, as it was examined here, adding to more alternative teaching-learning practices/processes and strategies (e.g., by using different tools).

Furthermore, from the results of this hybrid approach, it was made clear that the involvement of the LMS Moodle use was quite effective in the increase of the quality of the constructed CMs (as derived from the topological taxonomy score), under the COLL-MODE. This was based on the fact that LMS Moodle boosted the role of CM as a kind of template or scaffold to help organize/structure knowledge, even though the structure must be built up piece by piece with small units of interacting concept and propositional framework (Novak, 1990). Moreover, it was shown that shifting from not using to using LMS Moodle affects the CM-based collaboration, in terms of turn-taking and balance of collaboration.

Concluding Remarks and Future Trends

Concluding Remarks

The discussion upon the CM construction, stemming from the previous and new hybrid approaches presented in this chapter, has shown that the CM construction could reveal important information regarding the way CM fosters different students' interactions under SELF- and COLL-MODEs. As it was shown, the combination of the LMS use with the collaborative construction of CMs results in CMs with higher quality, in terms of the topological taxonomy scores, and more productive collaboration, as it is reflected in peers' active participation and balanced collaboration during the collaboratively constructed CMs. The hybrid approach mainly explored here sets new directions toward the enhancement of LMS use and computer-based concept mapping, forming a combined basis for a more pragmatic approach of Online Learning Environments (OLEs) and b-/c-learning environments, within the context of higher education. It is totally transparent to the user during the time when the CM-based collaborative and/or LMS-based interactions take place, supporting and enriching, in this way, OLEs and promoting, at the same time, peer-to-peer collaboration within the computer-based concept mapping environments.

From a more general perspective, the *blendedness* of media and/or pedagogies, as the combination of tools employed in an online and c-learning environment, or the combination of different educational approaches, should be seen as the thoughtful integration of classroom F2F learning experiences with the combination of online learning experiences and as a real tool capable for transformational (sociocultural) change. Furthermore, from different research study perspectives and levels of analysis, deeper understanding of the learning activity may lead to various fine-grained types of feedback and new potentialities of the educational tools' use that can be communicated accordingly, e.g., to the learning design, to the students, to the educational institutions, and to the research community. This is of course an ongoing procedure that verifies existing empirical results (as the ones presented here) and strives for emerging future, as glimpsed in the succeeding subsection.

Emerging Future

The different perspectives presented so far in this chapter provide an ample space for exploration in an emerging future that deepens even further into a variety of CM-related aspects, such as:

- Fuzzy logic-based modeling of the CM parameters.
- Exploration of the dynamic characteristics of CM parameters.
- Revelation of students' time-transition signatures regarding the realization of step sequences during the construction of the CM.
- Provision of reflective feedback.
- In a more extended view, incorporation of affective factors during the collaborative perspective of the CM construction (COLL-MODE), via a sentiment analysis of the chat text.

An epitomized description of these new pathways follows (sections "Fuzzy Logic-Based Modeling of the CM Parameters, Dynamic Characteristics of QoCM, Time Perspective, Reflective Feedback, and Affective Perspective").

Fuzzy Logic-Based Modeling of the CM Parameters

This pathway allows automatically created CmapTool metrics to be employed in the inference process, creating fuzzy variables that act either as initials or as intermediates. Following the same logic of the FuzzyQoI model (Dias & Diniz, 2013), nested fuzzy inference systems (FISs) could be used to form a connection between the students' activities in the CmapTool space and the quality of the produced CM (QoCM). Toward such effort, at the first level, three FISs, i.e., FIS1, FIS2, and FIS3, could be formed to output the CM values of CON, REF, and ORG, respectively, upon the initial variables of {Add, Move, Connect} for FIS1, {Delete, Resize, Modify} for FIS2, and {Concept, Linking phrase} for FIS3. In the second level of inference, CON, REF, and ORG could be considered as intermediate variables and used as inputs to the FIS4, which would output the value of CM activity (CMA). Finally, at the third level of inference, the CMA could be considered as intermediate variable and along with CM TaxScore might be used as inputs to the FIS5, which would output the QoCM as the final output of this FIS-based scheme. Work toward such direction can be found in Dias, Dolianiti, Hadjileontiadou, Diniz, and Hadjileontiadis (2016) and Dias, Dolianiti, Hadjileontiadou, Diniz, and Hadjileontiadis (2017).

Dynamic Characteristics of QoCM

The construction of a CM involves a series of steps that express its dynamic character. The CmapTool records such steps and relates them with a specific time stamp and a single action (e.g., addition of a linking phrase) or automatically nested ones (e.g., deletion of a concept and automatically its linking phrases and connecting arrows are also deleted). By means of the fuzzy logic-based model discussed in section "Fuzzy Logic-Based Modeling of the CM Parameters", the evolution of the CM can be estimated, i.e., the intermediate values of the {CON, REF, ORG, CMA} along with the final QoCM could be turned to a function of the construction steps. To achieve this, the cumulative sum of the variables acquired from the CmapTool could be considered, within the range of 10% up to 100% of the total number of steps involved per students' CM and used as input to the FIS-based model. Such an approach can reveal the different strategies that are followed by the students during the construction of the CM and shed light upon a more fine-grained approach of the way the CM is constructed, as captured by the dynamic estimation of the QoCM (Dias, Dolianiti, et al., 2017).

Time Perspective

Time is an important parameter in the learning context. For capturing the time management of the CM construction, the time stamp linked with CM construction steps, as provided by the CmapTools, can be further explored. In particular, the step transition time interval (STTI) (in seconds) can be estimated for each student across the whole duration of the construction of their CMs. This could be explained from the perspective of weighting in terms of fast and slow thinking. Variations in the STTI can reveal that some sequences of CM steps would have more weight, as they need more time to be considered before and/or during their realization, whereas others would have less, as they are almost coming from a "spontaneous-like" thinking. The latter resembles the approach of Kahneman (2011), who corresponds fast thinking to System 1 and slow one to System 2. Actually, System 1 is intuitive, automatic, unconscious, and effortless; it answers questions quickly through associations and resemblances; it is nonstatistical, gullible, and heuristic. Unlike System 1, System 2 is conscious, slow, controlled, deliberate, effortful, statistical, suspicious, and lazy (costly to use). System 2 is engaged when circumstances require. Rather, many of our actual choices in life, including some important and consequential ones, are System 1 choices and therefore are subject to substantial deviations from the predictions of the standard model. System 1 leads to brilliant inspirations but also to systematic errors (Kahneman, 2011). This interplay between System 1 and System 2, perhaps, is reflected in the estimated STTI values, expressing personalization and adaptivity in the student's pace and choices during the construction of the CM. Clearly, such metaphors could expand the validity of the QoCM and STTI as constructive feedback to cases where individual/special needs should be taken under consideration, avoiding info-exclusion.

Reflective Feedback

The estimated intermediate (i.e., CON, REF, ORG, CMA) and final QoCM outputs of the fuzzy logic-based model discussed in section "Fuzzy Logic-Based Modeling of the CM Parameters", seen also from a dynamic perspective as discussed in sections "Dynamic Characteristics of QoCM and Time Perspective", could be used as a reflective personalized feedback to the student, providing quantitative information for both micro-, meso- and macro-analysis perspectives. These multiple layers of approach and their stepwise presentation support the gradual provision of reflective feedback and enable students to elaborate on the feedback information and return to their map, in order to correct any errors. This reinforces student's ability to reflect on and analyze material so to form reasoned judgments, something that is central to critical thinking and deeper learning (Quinton & Smallbone, 2010).

Affective Perspective

Taking into account the COLL-MODE of a CM construction, it is inevitable not to consider the chat interaction between the peers as a fruitful source of information that reflects collaborative behaviors toward the final CM construction. Deepening in this further, apart from the content, the affective character of the chat text should also be taken into consideration, clearly advancing the added value of the CM as a collaborative platform. In this perspective, 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 (Medhat, Hassan, & Korashy, 2014).

In fact, nowadays, it is possible to combine the sentiment analysis with the CmapTools environment, providing tangible measures (e.g., sentiment score/ratio) of the peers' text affective character and its variation during the peers' collaboration for the CM construction. Such an example is the Twinword Sentiment Analysis API[3] that can be connected with the CmapTools and can find the tone of a (positive and negative) comment/post, in the chat dashboard. This API does not just read the text type response ("negative," "neutral," or "positive"), but also can determine what is considered positive or negative (see an indicative example in Table 6.1). In addition, the interpretation of the score and ratio of the sentiment analysis can be explained as follows[4]:

- The *score* (*sc*) indicates how negative or positive the overall text analyzed is. Anything below a score of $sc = -0.05$ is tagged as negative, and the ones above $sc = 0.05$ are tagged as positive; anything in between inclusively is tagged as neutral. In a more general perspective, however, score thresholds could be adapted accordingly, like $sc \in [-1, -0.15)$ for negative, $sc \in [-0.15, 0.15)$ for neutral, and $sc \in [0.15, 1.0]$ for positive.

[3] https://apiant.com/connect/Twinword-Sentiment-Analysis-to-IHMC-Cmap.

[4] https://www.twinword.com/blog/interpreting-the-score-and-ratio-of-sentiment/.

Table 6.1 An example of a sentiment analysis, API demo used to find out the tone of a sentence or paragraph ("negative," "neutral," or "positive"). For instance, the exemplified sentence (left column) got a positive evaluation (with score *sc*~0.546 > 0.15 and ratio *r*~0.872 close to 1) (right column)

Chat text excerpt	Text sentiment analysis results[a]

The idea you had in the concept map construction was great!
I would like to see how this will evolve in the next connection. Well done! Congratulations!
	{
	"type": "positive",
	"score": 0.54590407666667,
	"ratio": 0.87166873728978,
	"keywords": [
	{
	"word": "congratulation",
	"score": 0.954143277
	},
	{
	"word": "like",
	"score": 0.85434434
	},
	{
	"word": "great",
	"score": 0.797954407
	},
	{
	"word": "well",
	"score": 0.649925065
	},
	{
	"word": "see",
	"score": 0.214487297
	},
	{
	"word": "will",
	"score": 0.117922934
	},
	{
	"word": "have",
	"score": -0.162909152
	},
	{
	"word": "idea",
	"score": -0.083155932
	}
	],
	}

[a]https://www.twinword.com/api/sentiment-analysis.php

- The *ratio* (r) is the combined total score of negative words compared to the combined total score of positive words, ranging from −1 to 1.

The information of the sentiment engagement across the collaborative construction of the CM could reveal important aspects related with students' cognition, motivation, and personality; hence, it could shed light upon the better understanding of peer's behavior. Actually, now more than ever, it is evident that external social media networks affect the way opinions can be formed. In general, social media activate System 2 thinking (Kahneman, 2011), as they provide a platform for the students to construct and express an opinion that is significant to them. As the comments/texts posted on social media networks are displayed in an open environment, users are more likely to use System 2 thinking, since they know that their comments are going to be read and/or evaluated. At the same time, this can generate a positive form of social pressure and interaction, making the experience more enjoyable and increasing the participation of the students to collaborative activities, such as the COLL-MODE of the CM construction.

From the aforementioned emerging future perspectives, a hybrid approach of a CM construction environment could be envisioned, in which CmapTools could be combined with social media platforms (e.g., Facebook/Messenger/Skype), incorporating text sentiment analysis, iLMS, and modeling approaches, such as the ones presented in this chapter, fostering a more personalized, intelligent, collaborative, adaptive, and affective perspective of learning.

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Chapter 7
Integrating Free and Open-Source Software in the Classroom: Imprinting Trainee Teachers' Attitudes

Stefanos Armakolas, Chris Panagiotakopoulos, Anthi Karatrantou, and Dimitris Viris

Introduction

Nowadays, people are increasingly turning to open materials and applications to meet their learning needs and finding that there is a greater range of choice available than ever before. At the same time, openness is increasingly proposed as a solution within formal educational institutions. Whether a crisis of funding, organization, accessibility, curriculum pedagogy, or resources there is an open, networked approach that has been suggested to address the problem (Farrow, 2017).

Rowand (2000) presents a number of reasons that teachers use technology, such as to create instructional materials, keep administrative records, communicate with colleagues, find information for lesson planning, make multimedia presentations, etc., revealing that teacher technology use does not seem to be exclusively about student computer activity but appears to be related with teacher activity too (Papadiamantopoulou, Papadiamantopoulou, Armakolas, & Gomatos, 2016). Nevertheless, a more integrated approach about teacher technology use appears in Bebell, Russell, and O'Dwyer (2004), who demonstrate seven distinct scales measuring the use of technology by teachers for class preparation, professional e-mail use, delivering instruction, enhancement, grading, supporting students' use of technology during lesson, and supporting students' use of technology to create products.

While information and communication technologies (ICTs) can assist teaching at any level of education, competing demands of resources and high costs of related software impede the adoption of ICTs in educational institutions (Tong, 2004).

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Especially in primary and secondary education schools, which may have limited financial resources, the use of free and open-source software can help lower the cost barrier and support the incorporation of ICTs in the classroom (Sakellariou, 2016). This way, the teachers can exploit new available technologies and methodologies to reach and intrigue students (Kotwani & Kalyani, 2012). In addition to the above advantages, software gives the chance to both teachers and students to get feedback from teaching progress, knowledge, and comprehension. At the same time, software can be used in the context of cooperative learning, whereas it contributes to learning environment improvement at a great level.

Despite the continuous increase of technological resources that teachers can utilize during instruction along with the efforts made by the Greek educational system to establish more conducive conditions for a computer-supported learning in both primary and secondary education, limited research exists regarding the use of technology by computer-literate teachers, let alone the intention of technology use by computer-literate pre-service teachers (Papadiamantopoulou et al., 2016).

The purpose of this study is to imprint teachers' attitudes toward free and open-source software in education. For this purpose, a convenience sample of pre-service and in-service teachers studying at the 1-year Pedagogical Training Program of ASPETE (School of Pedagogical and Technological Education) in Patras, Greece, was used. The survey was carried out in the context of the course "educational technology-multimedia" in the unit of "open educational resources- free and open-source software."

Open Sources and Educational Software

According to Ischinger (2007), open sources are digital educational materials and applications that are openly and freely available to the educational community (teachers and students) for use and reuse in teaching, learning, and research (Armakolas, Panagiotakopoulos, & Magkaki, 2017; Misra, 2013; Smith & Lee, 2017).

The reason for funding openness is the simple and powerful idea that the world's knowledge is a public good and that technology in general and the World Wide Web in particular provide an extraordinary opportunity for everyone to share, use, and reuse knowledge (Atkins, Brown, & Hammond, 2007).

A defining feature of free and open-source software is that they are released under an intellectual property license that permits open use, adaptation, and repurposing. The digital nature of the resources has been instrumental in global distribution through the Internet. For learners, free and open-source software represent a profound shift in the way they study and access information (Komineas & Tassopoulou, 2016).

Regarding the computer science education in secondary schools, O'Hara and Kay (2003) argue that teachers and students can benefit from free and open-source software by taking advantage of a world-size laboratory and support stuff, as well as by giving them experience in large-scale software collaboration and development.

In Greece, free and open-source software is being communicated and supported by the Greek Free/Open Source Software Society, which is a nonprofit organization founded in 2008 by 29 universities and research centers. Its main goal is to promote openness through the use and the development of open standards and open technologies in education, public administration, and business in Greece (Sakellariou, 2016).

Concerning the necessary criteria to be met in order for free and open-source software to be appropriate for the educational field, no difference is noticed with those applied in other educational software (Carusi & Mont'Alvao, 2006; Ferguson & Buckingham Shum, 2012; Franklin & van Harmelen, 2009; Okada, Meister, Mikroyannidis, & Little, 2013; Panagiotakopoulos, Karatrantou & Pintelas, 2012).

More specifically:

- The content has to be relevant to curriculum, consistent with the cultural and moral context as well as with educational and social values.
- It has to be enriched with cross-curricular themes, scientifically well-documented, reliable without any inaccuracies, updated, and structured according to students' age.
- The content has to be strongly interactive promoting knowledge construction and comprehension, preventing students from learning retention.
- Software environment should be suitable for the cultivation of the students' aesthetic taste.
- Software should have a specific structure, rational connection, and cohesion in the context of a proper environment of interface and interaction.
- Software has to give the chance to teachers to enrich the content with extra exercises and activities, if needed.

Free and open-source software usage has significant benefits. Firstly, open-source software is always accompanied by a general public license that defines the free product distribution. That means that the installation of open-source software at a large number of computers is facilitated; for instance, when it comes to a corporate net, significant financial resources can be saved due to mass licenses' edition. In addition to this, the more users are getting involved in source's development, the easier is error detection and correction. Furthermore, colleagues often work in teams toward a common target. As a result, values, as collaboration, co-creation, and collective responsibility for the final product, are developed. Apart from the moral satisfaction, co-creators increase their dedication to the software's development and support. In this way, innovation is encouraged, and security and stable behavior is ensured.

On the other hand, there are obvious disadvantages, such as reliability issues, copyright infringement, or insecure software support. The risk of aspirant hackers to take advantage of software vulnerability and gain easy access in the code should not be underestimated (Delimpeis, 2008; Spyrakis, 2011).

The role of teachers' attitude toward free and open-source software is determinant in order to accomplish the objectives of software integration in the educational process (Kotwani & Kalyani, 2012; Mountridou & Soldatos, 2010).

Methodology: Sample and Data Collection

For the purpose of the study, a convenience sample (Cohen, Manion, & Morrison, 2013) from pre-service and in-service teachers studying at the 1-year Pedagogical Training Program of ASPETE in Patras was used. The final sample was compromised by 60 trainee teachers (in-service and pre-service) of both genders with a range of age from 26 to 40 years old. Thirty of them were in-service teachers with a teaching experience between 1 and 10 years, and 30 of them were pre-service teachers.

The research was based on primary data collected through a structured questionnaire including mainly closed-type questions. After the completion of the data collection tool and the appropriate corrections, a pilot test was conducted with four participants (excluded from the main research) to increase the validity of the used questionnaire.

The questionnaire was distributed online by the free web application of Google Drive and more specifically, Google Docs. According to Bell (2005), online questionnaires guarantee legible questions and answers and facilitate data processing. The purpose of the survey was to collect data in order to answer the research questions. Descriptive and explanatory data analysis was applied in order to imprint participants' characteristics, opinions, and attitudes. Kyriazi (2002) claims that quantitative research allows theoretical causal hypotheses to be tested what we attempted to do in the present study. However, one of the limitations of this survey was its small extent.

The questionnaire included 2 main sections with a total of 11 closed questions. First section contained four questions that intended to gather information about the use of educational software in education. Second section contained seven questions aiming at exploring concern, opinions, information level, and extent of open-source software's utilization in the educational process.

Findings

Data from a pilot test were analyzed, and corrections on the questions contributed on the questionnaire modification. The questionnaire used in the study appeared to have an acceptable internal consistency (Cronbach $\alpha = 0.78$).

Statistical analysis of the data based on x^2 goodness-of-fit test, x^2 test of independence, and Spearman coefficient of correlation used to test the significance of the results. The results of the study are presented and briefly discussed in the following paragraphs:

Improving the Educational Process by Using Educational Software Applications in Order to Achieve the Learning Objectives

All the participating teachers express positive attitudes toward the use of educational software applications in the classroom (educational process). Most of them (97.0%) express the opinion that the use of educational software applications into education contributes *much* and *very much* to the achievement of learning objectives (Fig. 7.1), while *little* 3.0%, *very little* 0.0%, and *not at all* 0.0%.

The results of the "goodness-of-fit" analysis showed significant differences between the responses [$\chi^2 = 41.2$; df = 2; $p < 0.01$].

The Use of Educational Software Applications in Education and the Intention to Use Them More

The majority of the teachers (70.0%) have used educational software in the classroom, but 30.0% of the participants have not used any educational software in the classroom. The results of the "goodness-of-fit" analysis showed also significant differences between the responses [$\chi^2 = 9.6$; df = 1; $p < 0.01$]. However, all of them (those who already use software in the classroom and those who don't) express their intention to use it in the future.

Due to the limited or in not good situation of technological infrastructure in Greek schools, it may be difficult for many teachers to use ICT applications in their lesson. On the other hand, many of them are not trained in how to use ICT to support and enhance their teaching and their students' learning.

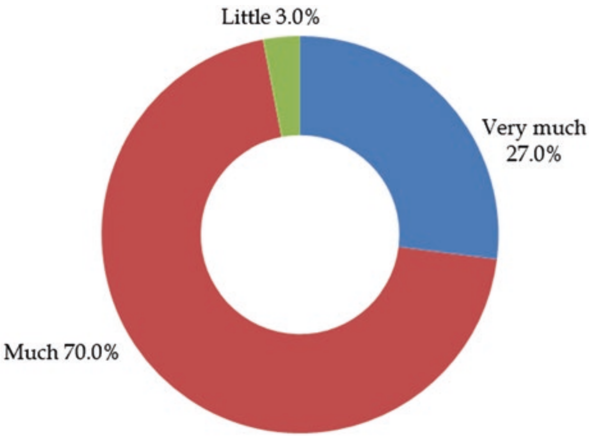

Fig. 7.1 The use of educational software applications can improve the educational process to achieve the learning objectives

Awareness of What Free and Open–Source Software Is

It is important to notice that half of the participants (50.0%) did not know what the free and open-source software is, but all of them would like to be informed and trained.

Using Free and Open–Source Software in the Classroom

The majority (67.0%) of the participants who are informed about free and open-source software use it in the classroom, but there is another 33.0% who are informed about free and open-source software without using it for educational purposes. "Goodness-of-fit" analysis didn't show significant differences between the responses [$\chi^2 = 3.33$; df = 1; $p > 0.05$]. That may due to the fact that teachers are trained to use the officially bought and installed in schools software, and they do not take the initiative to use something different and try it because they may feel unconfident.

Most of the teachers who use free and open-source software (70.0%) do not face any technical problem in contrary to a percenter of 30.0% who faces technical problems. "Goodness-of-fit" analysis didn't show significant differences between the responses [$\chi^2 = 3.32$; df = 1; $p > 0.05$].

What Free and Open-Source Software Do Teachers Use in Their Classroom?

The participants in the study who use free and open-source software in their classroom were asked to write down which software they use often.

As it is presented in Fig. 7.2, the software Open Office Suite (Writer word processor, Calc spreadsheet, and Impress for presentations) is used by the majority (86.67%) of the participants, the Mozilla FireFox browser is used by a high number of them (80.00%), and the file archiver to compress files 7-Zip is used by the 46.67% of the participants in the study. The integrated course management system Open eClass is used by the 33.33% of the teachers to support the learning process of their students. The participants seem to prefer the WordPress platform (26.67%) to create blogs and upload and manage educational material than the Joomla platform (13.33%).

The number of teachers who use PhP and MySQL to develop dynamic webpages is less than 20.00%. Many teachers use video for educational purposes by means of the VLC software (26.67%).

The cross-platform audio software Audacity is used during multimedia lessons for sound processing (13.33%). The programming language Scratch is used only by the 6.67% of the teachers participating in the study with students in primary school

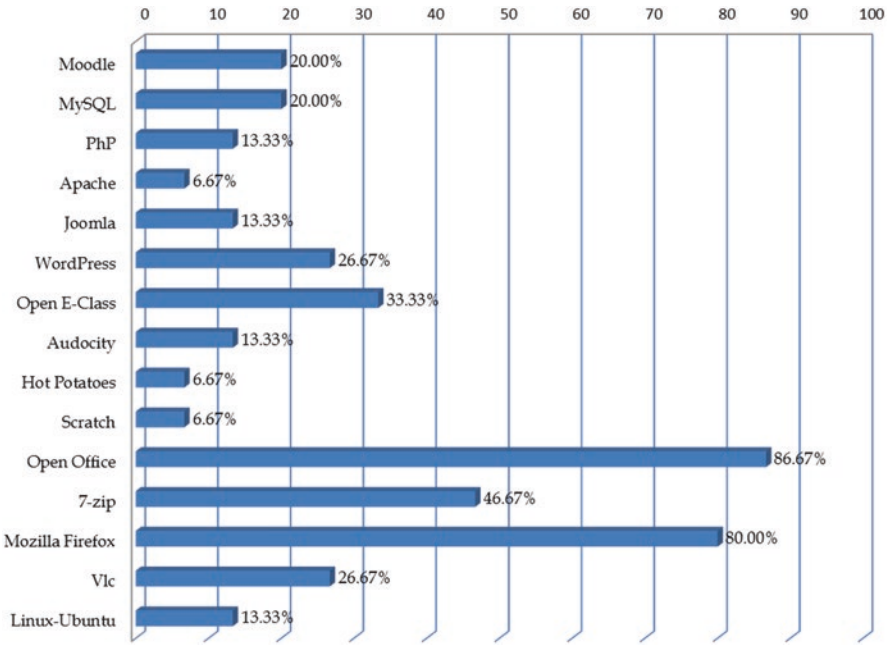

Fig. 7.2 Free and open-source software used in the classroom by teachers

or in junior high school. Just the 6.67% of the participants uses the *Hot Potatoes* software to create a quiz with multiple-choice, short-answer, jumbled-sentence, crossword, and matching/ordering questions. Linux operating system and more specifically Ubuntu is used by a very low number of teachers. In most schools, Microsoft operating system Windows is used, and all FOS applications are running on it, in case they are used by the teachers.

Teacher's Views About the Impact of Free and Open-Source Software in the Learning Environment

The great majority of the teachers in the study (93.0%) supports that the impact of the use of free and open-source software in the learning environment is important because it can trigger student's interest in the lesson and strengthen their participation as well. The results of the "goodness-of-fit" analysis showed significant differences between the responses [$\chi^2 = 22.53$; df = 1; $p < 0.01$].

The positive impact of the use of ICT in education is important according to the teacher's answers regardless the use of free and open-source software or non-free and open-source software in educational activities.

The Possibility of Exclusive Use of Free and Open-Source Software in Schools and Its Contribution to the School and Family Budget

The majority of the teachers who use free and open-source software in their classroom express positive views and attitudes toward the use of free and open-source software, the impact of it into achievement of learning objectives, and the improvement of the learning environment in general.

Only 27.0% of the participants think that the use of free and open-source software could be exclusive in schools, the 53.0% of them supports the opposite opinion and 20.0% of them are cautious (Fig. 7.3). The results of the "goodness-of-fit" analysis didn't show significant differences between the responses [$\chi^2 = 5.6$; df = 2; $p > 0.05$].

That may due to the fact that only half of the participants are informed about free and open-source software and its use in education. However, most of them (87.0%) recognize that its contribution to the school and family budget can be important. The results of the "goodness-of-fit" analysis in this question showed significant differences between the responses [$\chi^2 = 38.4$; df = 2; $p < 0.01$].

It is worth to be noticed that not any statistically significant difference derived based on the x^2 test of independence analysis between the responses of in-service teachers and pre-service teachers ($p > 0.05$), and spearman correlation coefficient didn't highlight any strong and significant correlation among the years of teaching experience and the teachers' responses to the questions under investigation ($0.29 < rs < 0.41$, $p > 0.05$).

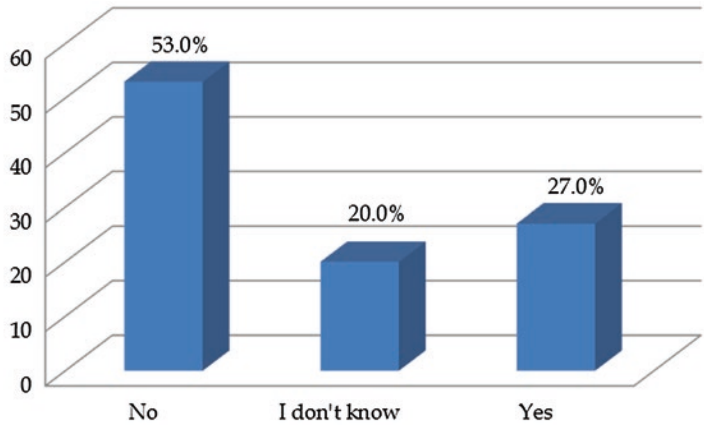

Fig. 7.3 Exclusive use of free and open-source software in schools

Discussion and Conclusions

The purpose of the study was to imprint teachers' attitudes toward free and open-source software in education. Sixty pre-service and in-service teachers studying at the 1-year Pedagogical Training Program of ASPETE in Patras (Greece) responded to the questions of a specific designed questionnaire. Analysis of the data derived from teachers' answers imprinted interested findings.

All the participating teachers express positive attitudes toward the use of educational software applications in the classroom, and most of them express the view that the use of educational software applications into education contributes *very much* to the achievement of learning objectives. The majority of the teachers have already used educational software in the classroom and expressed their intention to use it again in the future. However, participants who have not used educational software in the classroom answered that they have the intention to use it in the future.

Although, half of the participants were not aware about free and open-source software most all of them express positive views. The majority of the participants who were informed about free and open-source software use already it in their classroom. The majority of the teachers who use free and open-source software in their classroom express positive views toward the impact of free and open-source software into achievement of learning objectives and the improvement of the learning environment in general.

The great majority of the teachers in the study supports that the impact of the use of free and open-source software in the learning environment could be important triggering student's interest, strengthening their participation, and facilitating their collaboration.

However, the majority of the teachers support the opinion that the use of free and open- source software could not be exclusive in school. Most of them recognize that the free and open-source software contribution to the school and family budget can be important.

Teachers, who have already used free and open-source software, seem to prefer office applications, multimedia, and web browsers. That is a quite expected result since these applications can be used in a cross-curricular way, providing the teachers the chance to create tasks, prepare presentations, or present videos, without any specific technological knowledge to be required.

At the same time, specific programs that request specific background knowledge are applied less. Apart from application software, the use of operating systems is of great importance. Linux and especially Ubuntu edition seems to be popular operating system for teachers using free and open-source software. Nevertheless, Linux is limitedly used, and other operating systems are preferred instead, mainly Windows. Therefore, the majority of free and open-source software applications are installed in Windows operating systems.

Despite the fact that teachers referred to technical problems, their opinion about software contribution to learning environment development is, in vast majority, positively high. That means that software reinforces the creation and construction of new knowledge, playing a catalytic role in the development of new, contemporary teaching methods (Panagiotakopoulos, Karatrantou, & Pintelas, 2012; Panagiotakopoulos, Pierrakeas, & Pintelas, 2005). It is common knowledge that free and open-source software has already introduced in education, and it seems that it is going to be one of the main educational materials and tools in the future, as an increasing number of teachers will continue or attempt to use it (Sakellariou, 2016).

Nowadays, economic crisis and lack of school budget's financial resources appear to be an opportunity so that free and open-source software be further tested and integrated in education, as long as it satisfies the requirements of serving as educational software and ICT applications in education.

In any case, teachers, as proposed by them, need more and more substantial education, theoretical and practical training on relevant issues, appropriate infrastructure in their schools, curricula reformation, long-term educational planning by the state, and technical but mainly pedagogical support (mentors) to be able to cope with the new challenges. Findings from this research can be the basis for further research and contribute to the internationally developed dialogue with a view to a more effective integration of ICT in each level of education.

As it as mentioned above in the paper, openness @expresses and supports belief that the world‘s knowledge is a public good and that technology in general and the World Wide Web in particular provide an extraordinary opportunity for everyone to share, use, and reuse knowledge (Atkins et al., 2007; Komineas & Tassopoulou, 2016). In this frame, free and open-source software permits and supports open use, adaptation, and repurposing enabling learners to change the way they study and have access to information.

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Chapter 8
The Use of ICT and the Realistic Mathematics Education for Understanding Simple and Advanced Stereometry Shapes Among University Students

Nicholas Zaranis and George M. Exarchakos

Theoretical Background

ICT plays a main role in achieving the university curriculum objectives in a plethora of subjects and issues, if supported by developmentally appropriate educational software applications (Di Paola, Pedone, & Pizzurro, 2013; Dwyer, 2007; Papadakis, Kalogiannakis, & Zaranis, 2016). In the most ideal environment, computers are seen as instruments for teaching and learning processes (Burnett, 2009; Fisher, Denning, Higgins, & Loveless, 2012; Sutherland et al., 2004). They are used as educational devises for students to become even more familiar with modern technologies and the integration of communication, research, and comprehension of the curriculum.

As recorded by the international literature (Dissanayake, Karunananda, & Lekamge, 2007; Trouche & Drijvers, 2010; Wong, Yin, Yang, & Cheng, 2011), the use of ICT helped students to comprehend mathematical concepts in primary, secondary, and higher education. Regarding that, instructors have to find new methods to attract students based on their interest in computer-related fields and the industry needs (Shih, Jackson, Hawkins Wilson, & Yuan, 2014); we set out to explore the impact of our new stereometry model in the learning process and whether or not it produces better outcomes for university students.

The results of the various surveys concern the appropriate use of computers with the ability of students to understand the different mathematical concepts. Also, a large number of studies show a positive correlation between the use of computers and the progress of mathematical thinking at every level of education (Clements,

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2002; Dimakos, Zaranis, & Tsikopoulou, 2009; Walcott, Mohr, & Kastberg, 2009; Wong et al., 2011).

However, a lot of researchers found that although they have great features, computers are only as beneficial as the educational software used. Software made in accordance with the acquisitions of the educational system can contribute to the effective learning with the help of practice made under the guidance of teachers. Researchers realized that the software implemented for mathematics education is a very important factor in the teaching process (Flores, 2002; Judge, 2005; Keong, Horani, & Daniel, 2005; Trouche & Drijvers, 2010).

Dynamic multiple implementations in software help students' visualization because students can investigate, solve, and understand mathematical concepts using various methods. Providing only information or images is not enough to force students use a different understanding of mathematical knowledge (Antohe, 2010; Zengina, Furkanb, & Kutluca, 2011). Proper software offers a higher level of engagement in coordinate geometry (Dimakos & Zaranis, 2010; Sahaa, Ayubb, & Tarmizi, 2010).

In this research, teaching tools have been developed in order to engage students to understand stereometry concepts with the approach of the van Hiele model. Based on this idea, the software is designed for the purpose of this study and was based on the van Hiele model and the Realistic Mathematics Education (RME).

RME is a theory of teaching and learning mathematics. Indicative of this are the learning and teaching trajectories with intermediate attainment targets which were first conducted for the subject of mathematics and extended to the subject of geometry. In the whole trajectory of the RME teaching theory, five main characteristics of understanding geometry concepts (Freudenthal, 1973; Van den Heuvel-Panhuizen & Buys, 2008) are involved: introducing a problem using a realistic context, identifying the main objects of the problem, using appropriate social interaction and teacher intervention to refine the models of the problem, encouraging the process of reinvention as the problem develops, and focusing on the connections and aspects of mathematics in general.

Moreover, the theory of the van Hiele model, based on RME, deals specifically with geometric thought as it develops through several levels of sophistication under the influence of a university curriculum. The van Hiele model uses five levels (Van Hiele, 1986).

- Visual Level: This level is characterized by the students' perception of geometric shapes as entities, according to their appearance.
- Level of Analysis: At this level, students begin to distinguish between the properties of geometric shapes, making an analysis of the data perceived and to recognize these shapes by their properties.
- Level of Informal Deduction: At this level, students can infer properties of a shape and recognize categories of figures; they understand class inclusion and definitions.
- Level of Deduction: At this level, students can construct geometric proofs at secondary school level and understand their meaning. They understand the role of definitions, axioms, and theorems in Euclidean geometry.

- Level of Rigor: At this level, students understand that definitions are arbitrary and need not actually refer to any particular implementation. Also, they can study non-Euclidean geometry with understanding.

Following the theoretical framework that combines the van Hiele model and the use of ICT for undergraduate students, we designed a new model referred to as the Basic University Students Stereometry Model (BUSSM). This model applied to second year undergraduate students from the Department of Civil Engineering at Piraeus University of Applied Sciences. The BUSSM used only the first three levels of the van Hiele model focusing on projections, intersections, and expansions of points, line segments, planes, cubes, spheres, ellipsoids, cylinders, and cones, and it was a 5-week syllabus program.

Research Questions

The main objective of this study was to investigate the effects of teaching intervention using the BUSSM for basic and advanced stereometry concept and then compare this model to the traditional teaching approach. Thus, we set out to examine the following five research questions:

1. Will the students who will be taught stereometry based on BUSSM have a significant improvement, in their general stereometry achievement of basic and advanced stereometry concepts (points, line segments, planes, cubes, spheres, ellipsoids, cylinders, and cones), compared to those taught using the traditional teaching method in the current university curriculum?
2. Will the students who will be taught stereometry based on BUSSM have a significant improvement, in their basic stereometry concepts (points, line segments, planes, cubes, and spheres), compared to those taught using the traditional teaching method in the current university curriculum?
3. What is the stereometry level of students who had the highest benefit from BUSSM in basic stereometry concepts (points, line segments, planes, cubes, and spheres)?
4. Will the students who will be taught stereometry based on BUSSM have a significant improvement, in their advance stereometry concepts (ellipsoids, cylinders and cones), compared to those taught using the traditional teaching method in the current university curriculum?
5. What is the stereometry level of students who had the highest benefit from BUSSM in advanced stereometry concepts (ellipsoids, cylinders, and cones)?

The present study makes an important contribution to the literature; it examines and compares the effects of a new model which combines computer and noncomputer activities for teaching the projections and intersections of points, line segments, planes, cubes, and spheres as well as projections, intersections, and expansions of ellipsoids, cylinders, and cones.

Methodology

The present study was conducted in three phases. In the first and third phases, the pretest and posttest were given to the classes, respectively. In the second phase, the teaching intervention was performed.

Sample

The study took place during the 2013–2014 academic year in the Department of Civil Engineering at Piraeus University of Applied Sciences. It was an experimental research which compared the BUSSM teaching model to traditional teaching for second year undergraduate students.

The sample consisted of 189 second year students of the above department, who were divided into two groups randomly. In the experimental group (EG), the teaching approach of solid shapes was made with the use of ICT. In the control group (CG), the teaching approach used the traditional method.

The experimental group (EG) consisted of 99 students and had four classes of 30 or 31 students. In the EG, 122 students participated, but 23 students dropped the course or completed only 1 of the 2 required tests (pretest or posttest), and as a result, these students were not included in the sample. The participation rate in EG was 80.49%. The classes in the experimental group used ICT as part of the educational process.

The control group (CG) consisted of 90 students and had four classes of 29 or 30 students. In the CG, 118 students participated, but 28 students dropped the course or completed only 1 of the 2 required tests (pretest or posttest) and were not included in the sample. The participation rate in CG was 76.27%.

Research Design

The design of this study included three phases for all groups, experimental and control ones. There were:

1. The pre-experimental phase was at the beginning of April 2014 and lasted 2 weeks. Its purpose was to isolate the effects of the treatment by looking for inherent inequalities in the stereometry achievement of the two groups. The pretest was given to the students of the experimental and control groups.
2. The experimental phase or intervention phase was at the middle of May 2014 and lasted about 5 weeks. Students in the experimental and control groups participated in the university course “Drawing with ICT” in the fourth semester. At the beginning of this course, students were taught to use various 3D software features and capabilities on applications such as AutoCAD, ArchiCAD, and

CadWare, which are ideal for use in the learning process (Abu Ziden, Zakaria, & Nizam Othman, 2012). The objective of this course is to familiarize students to create various digital designs with the use of computer applications. It is divided into two main parts: the theoretical part and the practical part. In the first part, students use a graphic design program in order to produce building design, topography, and general civil engineering designs. Students are confronted with an introductory educational presentation for the use of various design software. Throughout this part, students realize that all the different software they are presented works in similar ways to perform similar tasks. Using this method, we stimulate the interest of students and help raise their confidence. In the second part, the students apply the knowledge they gained in the first part of this course by performing labs with graphical design software. At the end of the course, the students were able to create 3D stereometry shapes using various graphical design software. Following that, at the end of the course, the students were divided into two groups (experimental and control) randomly and voluntarily participated in the research. The teaching process of the experimental and control groups will be further explained in the following subsections.

3. The post-experimental phase was in the middle of June 2014, which aimed to measure the children's overall improvement. The same test was given to all students in both the experimental and control groups as a posttest to measure their improvement on advanced stereometry concepts.

Ethical considerations and guidelines on the privacy of students and other relevant ethical issues in social research were carefully considered throughout the process of research. Requirements relating to information, informed consent, confidentiality, and use of data held carefully, both orally and in writing, by informing academic staff and students of the purpose of the study and of their rights to refrain from participation. Therefore, the names of the participants and their scores on either of the tests were not made public at any time during this study.

Measures

In the pre-experimental phase, the first phase, the pretest was administered to assess the students' basic and advanced stereometry competence, and it contained 54 tasks in total. There were pencil-and-paper tasks in which students were asked to identify the projections of basic shapes including planes (Fig. 8.1a), spheres, cubes (Fig. 8.1b), points, and line segments and the projections, intersections, and expansions of ellipsoids, cylinders, and cones (Fig. 8.2a, b). There was about an equal number of tasks for the evaluation of each of the stereometry shapes. Each task had a weighted score that came from the students' answers. Scores were evaluated for each of the individual tasks of the stereometry test. The pretest and posttest were administrated in the class with explicit and specific instructions from the teachers, and each test lasted about 50 min.

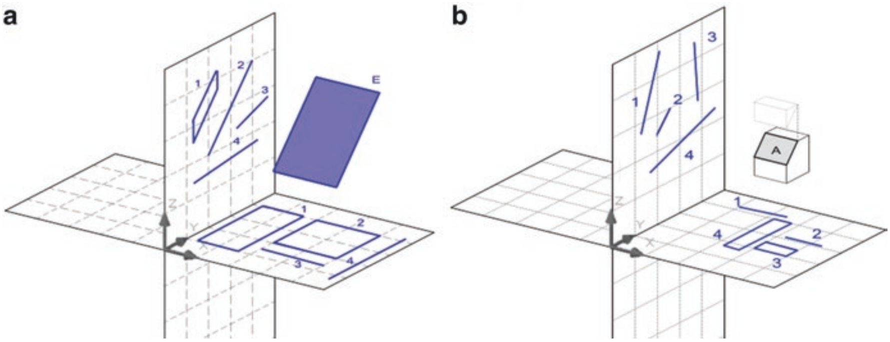

Fig. 8.1 Evaluation sheet for the projection of the plane E (**a**, left) and the projection of the intersection A of the cube (**b**, right)

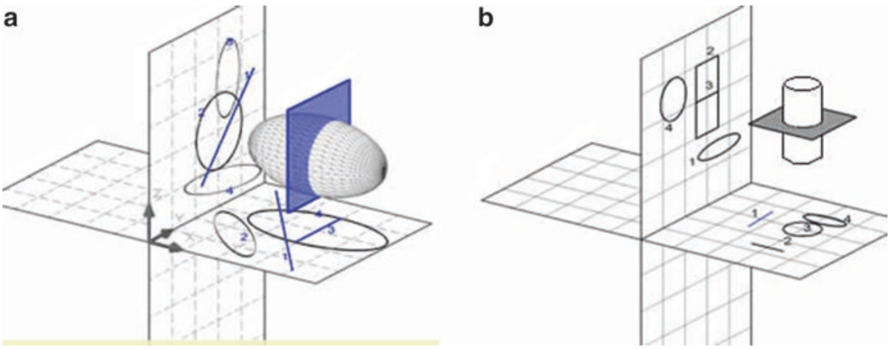

Fig. 8.2 Evaluation sheet for the projection of the ellipsoid (**a**, left) and the projection of the cylinder (**b**, right)

Similarly, during the third and final phase of the study, the post-experimental phase after the teaching intervention, the same test was given to all students in both the experimental and control groups, as a posttest to measure their improvement.

Teaching for Control Group

The control group learned basic and advanced stereometry concepts with the traditional approach. The total time of each class was 10 h long, and the course lasted 5 weeks in total. It included concepts such as projection and intersections of points, line segments, planes, cubes, and spheres and also projections, intersections, and expansions of ellipsoids, cylinders, and cones in a three-dimensional coordinate system. Only traditional teaching methods (Fig. 8.3) using the dry-erase board were implemented. The teacher presented the theory about basic and advanced concepts of stereometry. After the presentation of the theory, students were encouraged to ask

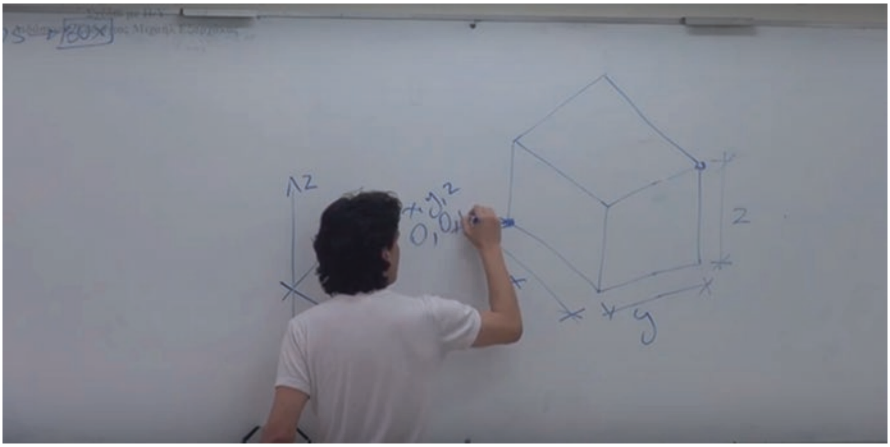

Fig. 8.3 Teaching stereometry with traditional way

questions regarding the lesson. At the end of each module, example problems were solved by the teacher on the dry-erase board. Afterward, the teacher answered any questions the students may have had.

Teaching for Experimental Group

The experimental group was taught using ICT intervention according to our model, presenting the same concepts as the control group. The teaching approach was completed in three stages, according to the Basic University Students Stereometry Model (BUSSM).

The first stage started with educational software for teaching the projections and intersections of points, line, segments, planes (Fig. 8.4a, b), cubes, and spheres in a three-dimensional coordinate system. The teaching of these concepts lasted 4 h. During the first 2 h, the students were taught according to the first two levels of the van Hiele model. During the second half of the lesson, the concepts of points, line, segments, planes, cubes, and spheres were presented based on the third level of the van Hiele model.

The second stage consisted of educational software for teaching the intersections and projections of ellipsoids, cylinders, and cones (Fig. 8.5) and lasted 4 h. During the first 2 h of this stage, the concepts introduced were based on first and second levels of the van Hiele model. During the second 2 h, the teaching process was based on the third level of the van Hiele model.

The third stage consisted of educational software for teaching the expansions of ellipsoids, cylinders, and cones and lasted 2 h. During the first hour, the concepts introduced were based on the first and second levels of the van Hiele model. During the second hour, the teaching process was based on the third level of the van Hiele model.

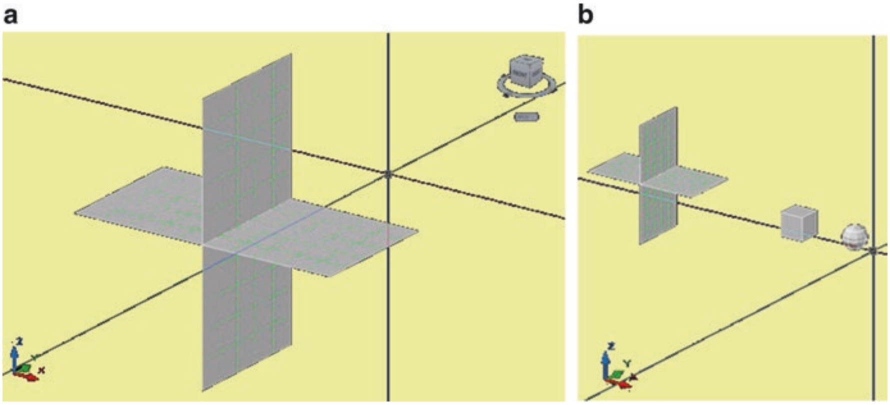

Fig. 8.4 Constructing the three-dimensional coordinate system (**a**, left) and the basic solid shapes (**b**, right) with the use of ICT

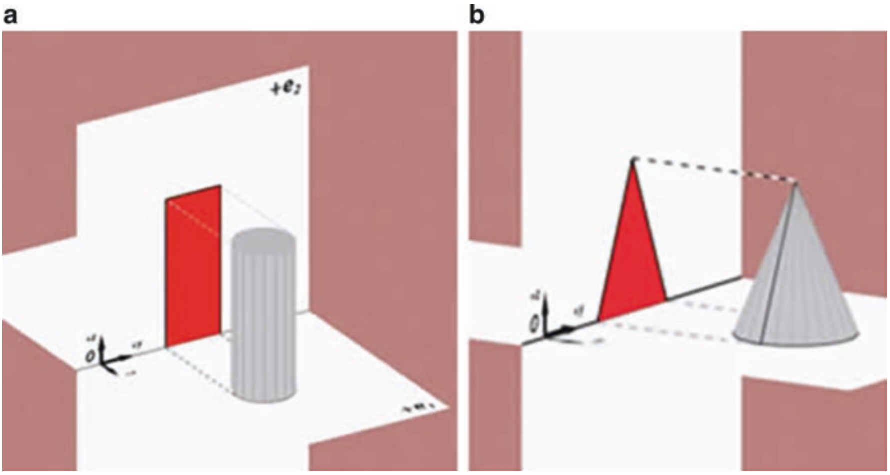

Fig. 8.5 Teaching projections of a cylinder (**a**, left) and a cone (**b**, right) with the use of ICT

In this teaching process, the tasks of the BUSSM intervention were allocated equally to all subjects. Also, during the teaching intervention, exercises were created that were included in the van Hiele model. During the teaching approach, each stereometry concept was investigated by the students through the first three van Hiele levels. At the first level, the visual level, students were able to identify, name, reproduce, and group together stereometry objects using visual recognition. For instance, students might define that an object is a cube, because it looks like a dice. Also, students might say that an object is a cylinder, because it looks like a tin can. At the second level, the level of analysis, the students were able to identify stereometry shapes by their properties. For example, a student sees a cube as a shape with all plane surfaces equal. Also, a student recognizes that a cylinder has two circular plane surfaces, one at its base and another at its top, and also that it has a curved surface in the middle. At the third level, the level of informal deduction, the student can reason with simple arguments about stereometry figures. The student recognizes the relationships between types of shapes. For example, he can find out that the projection of a line segment which is vertical to a plane is the same as the projection of a point. Also, the student can find out that a sphere is an ellipsoid which has distinct semi-axes of equal length. During the teaching approach of these three levels, video tutorials (Fig. 8.6) were presented by the educator displaying solid shapes and their properties, projections, and intersections (e.g., a video tutorial with projections of cone intersections). A discussion then followed to answer any questions the students may have had. Also, the students had to construct the shapes on the computers using the AutoCAD program system (Abu Ziden et al., 2012). This was an interactive way to view and understand the properties of the stereometry objects and see them from many different points of view. Moreover, the students performed projections and various intersections of the stereometry shapes. In addition, exercises were assigned by the teacher, and students were required to solve them using the AutoCAD program.

The AutoCAD program was used for projections and intersections of various stereometry shapes. This is the software that enables the creation of stereometry models using and specifying coordinates based on the Cartesian axes system (Abu Ziden et al., 2012). Using this software, the student can create objects in two and even three dimensions to see a various range of projections. Also the students used the software to link objects in Cartesian coordinate system and create new intersections of stereometry objects. The students even had the ability to rotate the entire stereometry shapes or parts of them in real time. Using this software, the student can determine the results of operations and fully understand the properties of shapes in a three-dimensional environment. The 3D Studio Max program was then used to create and move three-dimensional stereometry shapes. Students in several investigations with the 3D Studio Max program found the interactive multimedia teaching methods to be a valuable supplement to the conventional teaching process (Prinz, Bolz, & Findl, 2005). Finally, the Camtasia software was used. Camtasia Studio has been suggested as suitable applied software to create educational content (Bauk & Radlinger, 2013). It had a user-friendly interface for creating multimedia, providing students with a variety of options for educational presentations. It uses the introduc-

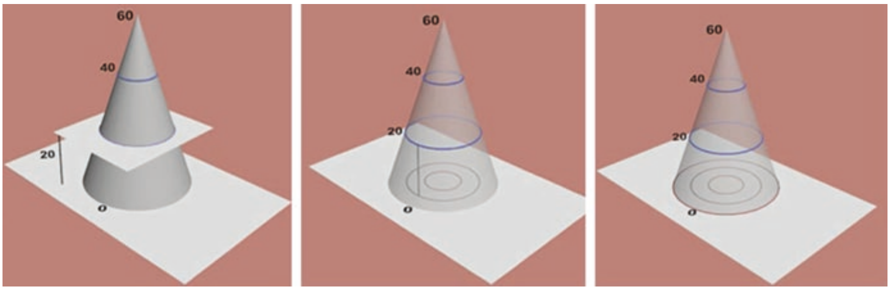

Fig. 8.6 Screenshots from a video tutorial of projections of cone intersections

tion of sound, video, and various animations in order to make teaching and learning more interesting and to highlight the most important subjects. In our application, it has been used to process animated images and add comments on the screen.

Results

Analysis of the data was carried out using the SPSS (ver. 19) statistical analysis computer program. The independent variable was the group (experimental group and control group). The dependent variable was the students' posttest score.

Evaluate the Effectiveness of BUSSM for General Stereometry Achievement

The first analysis was a *t*-test among the students' pretest scores of stereometry achievement in order to examine whether the experimental and control groups start from the same level. There was a significant difference in the students' pretest scores for experimental ($M = 0.534$, SD = 0.100) and control groups ($M = 0.613$, SD = 0.169); $t(141.635) = -3.838$, $p < 0.001$. As a result, an ANCOVA analysis will be processed.

Before conducting the analysis of ANCOVA on the students' posttest scores for general stereometry achievement 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 pretest for general mathematical achievement was included in the model as a covariate was not significant, indicating that the group variances were equal, $F(1, 187) = 1.073$, $p = 0.302$; hence, the assumption of homogeneity of variance was not been violated.

After adjusting for scores for general stereometry achievement in the pretest (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 posttest scores for general stereometry achievement, $F(1, 186) = 35.899$, $p < 0.001$, partial eta squared = 0.162 (Table 8.1); thus, the experimental group performed significantly higher in the posttest for general stereometry achievement than the control group.

Table 8.1 Comparison of student scores for total mathematical achievement in posttest: ANCOVA analysis

Sources	Type III sum of squares	df	Mean squares	*F*	Sig.	Partial eta squared
Pretest	3.072	1	3.072	128.299	0.000	0.408
Group	0.859	1	0.859	35.899	0.000	0.162
Error	4.453	186	0.024			

Table 8.2 Comparison of student scores on basic stereometry concepts in posttest: ANCOVA analysis

Sources	Type III sum of squares	df	Mean squares	*F*	Sig.	Partial eta squared
Pretest	2.005	1	2.005	151.581	0.000	0.449
Group	0.155	1	0.155	11.680	0.001	0.059
Error	2.460	186	0.013			

Evaluate the Effectiveness of BUSSM for Basic Stereometry Concepts

Then, a *t*-test analysis performed among the students' pretest scores of basic stereometry concepts (projections and intersections of points, line, segments, planes, cubes, and spheres) in order to examine whether the experimental and control groups start from the same level.

There was a significant difference in the students' pretest scores of basic stereometry concepts for experimental ($M = 0.547$, SD = 0.135) and control groups ($M = 0.599$, SD = 0.190); $t(159.123) = -2.117$, $p = 0.036$. As a result, an ANCOVA analysis will be processed.

Also, before conducting the analysis of ANCOVA on the students' posttest scores for basic stereometry concepts 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 pretest for basic stereometry concepts was included in the model as a covariate was not significant, indicating that the group variances were equal, $F(1, 187) = 0.001$, $p = 0.977$; hence, the assumption of homogeneity of variance was not been violated.

After adjusting for scores for basic stereometry concepts in the pretest (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 posttest scores for basic stereometry concepts, $F(1, 186) = 11.680$, $p = 0.001$, partial eta squared = 0.059 (Table 8.2); thus, the experimental group performed significantly higher in the posttest for basic stereometry concepts than the control group.

Evaluating the Stratification of Students in Basic Stereometry Concepts After the Teaching Intervention According to Their Success in Pretest

Moreover, a stratification of experimental and control groups according to their success in basic stereometry concepts of the pretest was divided into three equal categories: less than 0.499 (33.33th percentile—low), 0.500–0.613 (33.33th to 66.66th percentile—medium), and more than 0.614 (66.66th percentile—high). In Table 8.3, the students' performance is presented including both groups (i.e., the experimental and the control groups) before teaching intervention.

Table 8.3 shows that 20.2% of the students of the experimental group exhibited high grading and 41.4% exhibited medium grading, whereas 38.4% exhibited low grading. Likewise, 48.9% of the control group exhibited high grading, 24.4% medium, and 26.7% low. In other words, students' performance in the medium category of the experimental group appeared to be superior (i.e., 41.4% compared with 24.4% of the control group).

A two-way ANOVA was conducted that examined the effect of class (experimental versus control) and the students' level of mathematical achievement (low versus medium versus high) on their improvement on basic stereometry concepts (posttest minus pretest score). There was not a significant interaction between the effects of class and mathematical level on students' according to their success in basic stereometry concepts, $F(2, 183) = 0.969$, $p = 0.381$, partial eta squared = 0.010. On the contrary, the effect of mathematical level was significant ($F(2, 183) = 16.730$, $p < 0.001$, partial eta squared = 0.155), with the improvements of basic stereometry concepts in the low and medium levels higher (low, $M = 5.089$, SD = 2.624, medium, $M = 4.580$, SD = 2.551) than those in the high level ($M = 2.352$, SD = 2.094) after the teaching intervention (Table 8.4, Fig. 8.7). Also, the effect of group was also significant ($F(1, 183) = 6.419$, $p = 0.012$, partial eta squared = 0.034), with children in the experimental group scoring higher ($M = 4.724$, SD = 2.369) than those in the control group ($M = 3.187$, SD = 2.818) after the teaching intervention.

Table 8.3 Frequencies of the two groups in the pretest of general stereometry achievement

Pretest	Experimental group		Control group	
Grading	*N*	*f%*	*N*	*f%*
Low	38	38.4	24	26.7
Medium	41	41.4	22	24.4
High	20	20.2	44	48.9
Total	99	100.0	90	100.0

Table 8.4 Mean and standard deviation of mathematical improvement in basic stereometry concepts according to the levels of general mathematical achievement of the pretest

Level	Class	*M*	SD	*N*
Low	Experimental	5.215	2.551	38
	Control	4.889	2.778	24
	Total	5.089	2.624	62
Medium	Experimental	5.127	2.135	41
	Control	3.562	2.9763	22
	Total	4.580	2.551	63
High	Experimental	2.968	1.611	20
	Control	2.071	2.241	44
	Total	2.352	2.094	64
Total	Experimental	4.724	2.369	99
	Control	3.187	2.818	90
	Total	3.992	2.698	189

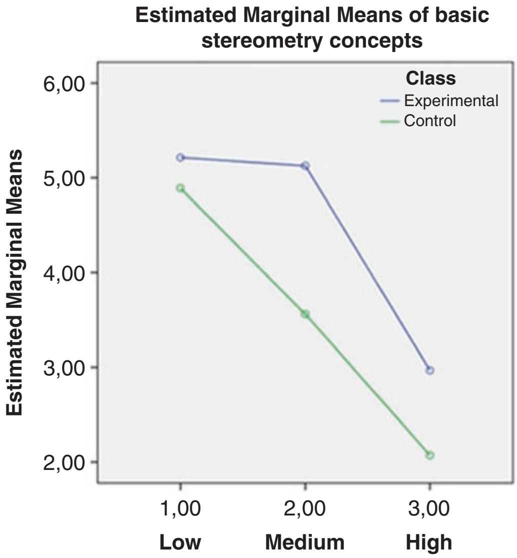

Fig. 8.7 Mathematical improvement in basic stereometry concepts after the teaching intervention according to the levels of general mathematical achievement of the pretest

The Bonferroni post hoc tests indicated that students' improvement in basic stereometry concepts of the experimental group of the low-level and medium-level groups differed significantly from students' improvement of the high-level group ($p < 0.001$ for low-level and $p = 0.018$ for medium-level).

Evaluate the Effectiveness of BUSSM for Advanced Stereometry Concepts

Initially, a *t*-test analysis was performed among the students' pretest scores for advanced stereometry concepts (intersections and projections of ellipsoids, cylinders, and cones) in order to examine whether the experimental and control groups start from the same level. There was a significant difference in the students' pretest scores of advanced stereometry concepts for experimental ($M = 0.526$, SD = 0.109) and control groups ($M = 0.621$, SD = 0.177); $t(145.541) = -4.373$, $p < 0.001$. As a result, an ANCOVA analysis will be processed.

Also, the analysis of ANCOVA on the students' posttest scores for subtraction was performed to evaluate the effectiveness of the intervention. The result of Levene's test when pretest for advanced stereometry concepts was included in the model as a covariate was not significant, indicating that the group variances were equal, $F(1, 187) = 3.159$, $p = 0.077$; hence, the assumption of homogeneity of variance was not been violated.

Table 8.5 Comparison of student scores for advanced stereometry concepts in posttest: ANCOVA analysis

Sources	Type III sum of squares	df	Mean squares	*F*	Sig.	Partial eta squared
Pretest	0.904	1	0.904	60.580	0.000	0.246
Group	0.408	1	0.408	27.320	0.000	0.128
Error	2.776	186	0.015			

After adjusting for scores for advanced stereometry concepts in the pretest (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 posttest scores for advanced stereometry concepts, $F(1, 186) = 27.320$, $p < 0.001$, partial eta squared = 0.128 (Table 8.5); thus, the experimental group performed significantly higher in the TEMA-3 posttest for advanced stereometry concepts than the control group.

Evaluating the Stratification of Students in Advanced Stereometry Concepts After the Teaching Intervention According to Their Success in Pretest

Moreover, a stratification of experimental and control groups according to their success in general mathematical achievement was divided into three equal categories, less than 0.499 (33.33th percentile—low), 0.500–0.613 (33.33th to 66.66th percentile—medium), and more than 0.614 (66.66th percentile—high), as it has been showed in Table 8.3.

A two-way ANOVA was conducted that examined the effect of class (experimental versus control) and the students' level of mathematical achievement in advanced stereometry concepts (low versus medium versus high) on their improvement after the teaching intervention (posttest minus pretest score). There was not a significant interaction between the effects of class and mathematical level on students' in advanced stereometry concepts, $F(2, 183) = 0.714$, $p = 0.491$, partial eta squared = 0.008. On the contrary, the effect of mathematical level in advanced stereometry concepts was significant ($F(2, 183) = 18.509$, $p < 0.001$, partial eta squared = 0.168), with the improvements of advanced stereometry concepts in the low and medium levels higher (low, $M = 10.746$, SD = 5.921, medium, $M = 8.191$, SD = 5.205) than those in the high level ($M = 4.421$, SD = 3.737) after the teaching intervention (Table 8.6, Fig. 8.8). Also, the effect of group was significant ($F(1, 183) = 34.211$, $p < 0.001$, partial eta squared = 0.158).

The Bonferroni post hoc tests indicated that students' improvement in advanced stereometry concepts of the experimental group of the low-level group differed significantly from students' improvement of the high-level ($p < 0.001$) group.

Table 8.6 Mean and standard deviation of mathematical improvement in advanced stereometry concepts according to the levels of general mathematical achievement

Level	Class	*M*	SD	*N*
Low	Experimental	12.369	6.461	38
	Control	8.175	3.820	24
	Total	10.746	5.921	62
Medium	Experimental	9.994	4.313	41
	Control	4.830	5.134	22
	Total	8.191	5.205	63
High	Experimental	6.536	2.664	20
	Control	3.460	3.781	44
	Total	4.421	3.737	64
Total	Experimental	10.207	5.414	99
	Control	5.052	4.560	90
	Total	7.752	5.638	189

Discussion

The overall aim of the study was to investigate the effect of the didactic intervention, using the Basic University Students Stereometry Model (BUSSM). Especially, mathematical activities and software based on Realistic Mathematics Education were designed for the purpose of teaching the mathematical concepts of basic and advanced stereometry concepts (Freudenthal, 1973; Van den Heuvel-Panhuizen & Buys, 2008). In this survey, we found that students taught with educational intervention based on BUSSM had significant improvement in their general stereometry achievement compared to those taught using the traditional teaching method according to the university curriculum. Our findings agree with similar studies (Antohe, 2010; Judge, 2005; Keong et al., 2005; Walcott et al., 2009; Zaranis, 2011), which implied that ICT helps students understand mathematical concepts more effectively. As a result, the first research question was answered positively.

Moreover, we found that students taught with the educational intervention based on BUSSM had significant improvement in basic stereometry concepts, such as projections and intersections of points, line segments, planes, cubes, and spheres in comparison to those taught using the traditional teaching method according to the university curriculum. Our results coincide with the results of other similar studies showing the positive impact of a computer-based model of teaching mathematics (Dissanayake et al., 2007; Kroesbergen, Van de Rijt, & Van Luit, 2007). Therefore, the second research question was confirmed.

Also, our findings suggest that students belonging to the low and medium level of general stereometry achievement being taught basic stereometry concepts with educational intervention based on BUSSM had significant improvement, compared to the students in the high levels of general mathematical achievement. Our results exceeded the outcomes of other similar studies showing the positive results of a computer-based model of teaching mathematical concepts for the low-level students (Keong et al., 2005; Zaranis, 2011). So the third research question was addressed.

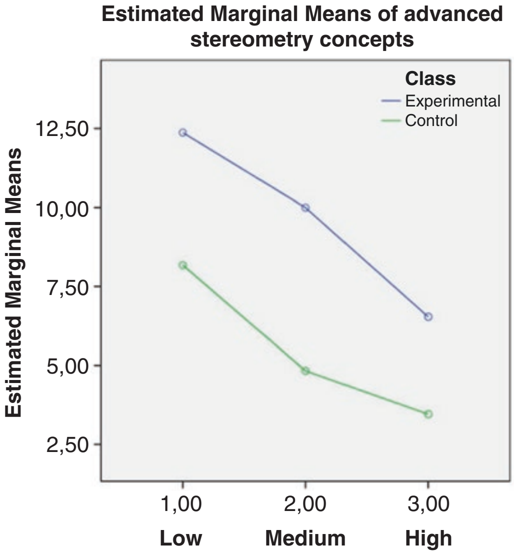

Fig. 8.8 Mathematical improvement in advanced stereometry concepts after the teaching intervention according to the levels of general mathematical achievement

Furthermore, as mentioned in the results section, the students taught with educational intervention based on BUSSM had a significant improvement on advance stereometry concepts, such as projections, intersections, and expansions of ellipsoids, cylinders, and cones, than those taught using traditional teaching according to the university curriculum. Our results agree with the results of other similar studies showing the positive outcomes of a computer-based model of teaching mathematical concepts (Dimakos & Zaranis, 2010; Howie & Blignaut, 2009; Starkey, Klein, & Wakeley, 2004; Trouche & Drijvers, 2010; Wong et al., 2011). Therefore, the fourth research question was also answered positively.

Moreover, our findings suggest that students with a low level of general stereometry achievement being taught advance stereometry concepts with educational intervention based on BUSSM had significant improvement, compared to those with a high level of general mathematical achievement students. Our results exceeded the outcomes of other similar studies showing the positive results of a computer-based model of teaching mathematical concepts for the low-level students (Dimakos et al., 2009; Keong et al., 2005). Thus, the fifth research question was also 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 universities' 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 students to understand stereometry concepts. Moreover, the learning method based on Realistic Mathematics Education (RME) using ICT can interfere in various mathematical subjects, e.g., algebraic equations, probabilities, etc.

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 in the city of Athens, Greece. The second limitation was the generalizability of this study which was limited to participants attending the Department of Civil Engineering at Piraeus University. As a result, the outcomes from this research can be generalized only to similar groups of students. The results may not adequately describe students from other regions of Greece. However, as the study was on specific context, any application of the findings should be done with caution.

Furthermore, the undertaken computer-assisted educational procedure revealed an extended interest for the tasks involved from the part of the students. It is an ongoing challenge for the reflective university teachers to decide how this technology can be best utilized in education. This study is one small piece in the puzzle of mathematics education in university level.

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Chapter 9
Integration of Technologies in Higher Education: Teachers' Needs and Expectations at UTAD

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Introduction

The use of ICT is a challenge for teachers and students. Despite its added value for teaching and learning processes, there are factors that influence its effective adoption. The successful utilization of technologies in the classroom depends mainly on teachers' attitudes toward these tools and their acceptance and real use of them (Al-Zaidiyeen, Mei, & Fook, 2010).

ICT teaching, as a complement to face-to-face instruction, improves the learning experience globally (Dahlstrom & Bichsel, 2014). The use of ICT in higher education provides opportunities for faculty to develop pedagogically rich courses and improve teaching and learning.

The benefits of use of ICT in teaching and learning processes are at different levels. At the pedagogical level, the benefits can be from the increase of learning effectiveness, satisfaction, and efficiency (Graham, 2013) to the increase of access and flexibility of educational practices, adapted to the demands of the labor world (Moskal, Dziuban, & Hartman, 2013; Wallace & Young, 2010). On the other hand,

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the use of ICT increases the access to higher education offerings and provides institutions to reach new audiences regardless of physical location, as well as affords teachers' and students' enhanced temporal and geographic flexibility to manage their part of the educational process (King & Arnold, 2012).

However, a process of diffusion of ICT in higher education must take into account the contextual, cognitive, and affective factors that are considered critical to its success, as the fear of change, the perception of increased workload, and the relation between the cost of investment and the opportunity for innovation (Ertmer & Ottenbreit-Leftwich, 2013). These are examples of factors that may negatively influence the individual predisposition to accept and incorporate the process of adaptation to new technologies in teaching (Maia et al., 2017).

Sang, Valcke, Braak, and Tondeur (2010) have verified that the adoption of ICT in classrooms is affected by various factors, such as the capacity of resources, the sustainability of the infrastructure, or teacher skills and attitudes.

Other scholars have examined factors that influence faculty adoption of different types of educational technology (Findik & Ozkan, 2013; McCann, 2010; Mtebe & Raisamo, 2014; Ngimwa & Wilson, 2012), identifying barriers and facilitators of the process. In their study, Lin, Huang, and Chen (2014) conclude that teachers' greatest barriers to ICT adoption included insufficient support and insufficient time for developing technology-driven pedagogy and activities. Others identified as main barriers heavy workloads leading to lack of time, lack of motivation, and lack of financial support (Oh & Park, 2009).

We have witnessed a stagnation of the integration and use of ICTs in teaching and learning processes (Hasan & Laaser, 2010). Ertmer and Ottenbreit-Leftwich (2013) research results allow to conclude that most teachers are not using technology to effect meaningful changes in student outcomes, using it as aids to deliver content.

Teachers' attitudes and motivation toward ICT are considered as major predictors of the use of new technologies in the educational processes (Al-Zaidiyeen et al., 2010). In the same way, teachers' pedagogical beliefs play an important role in the use of ICT in the classroom (Prestridge, 2010). That is why all these factors should be considered in any approach to teacher professional development (Albion, Tondeur, Forkosh-Baruch, & Peeraer, 2015).

Aware of the importance of teacher professional development to effectiveness of use of ICT in teaching and learning processes, the European Commission includes in the Digital Agenda for Europe actions for promoting various initiatives aimed at increasing training in digital skills, modernizing education across the EU, and harnessing digital technologies for learning. The value of ICTs in supporting the learning and teaching process and increasing the capacities of teachers is well understood by member states.

Research Design

UTAD Institutional Context

The University of Trás-os-Montes e Alto Douro (UTAD) is a Portuguese higher education institution located in Vila Real, northeastern Portugal. The educational offer at UTAD is organized into five schools: School of Agricultural and Veterinary Sciences (ECAV, Portuguese-language acronym), School of Sciences and Technology (ECT, Portuguese-language acronym), School of Life and Environmental Sciences (ECVA, Portuguese-language acronym), School of Humanities and Social Sciences (ECHS, Portuguese-language acronym), and Higher School of Health (ESS, Portuguese-language acronym).

Regarding the adoption of ICT in educational practices by teachers at UTAD, there is a support team, composed by experts in instructional design and pedagogical aspects and experts in technical support in the use of different technological tools and systems. This team has an activity plan with clear goals. This plan is based on four axes of action: (1) lifelong learning and training, (2) cooperation and development, (3) management and sustainability, and (4) research and dissemination of actions and results.

UTAD makes available for its community several technological tools for support teaching and learning processes, namely, the Education Information System (SIDE—Portuguese-language acronym), the LMS Moodle, and the Panopto platform, among others with different purposes as videoconference (Colibri), online repository of scientific work, streaming (Educast), and survey platform (LimeSurvey). SIDE is largely used by teachers and students, because it is the main system to manage teaching and learning processes. Moodle is used in a more modest way, as there are only 40 teachers (18 from ECAV, 6 from ECT, 8 from ECHS, 6 from ECVA, and 2 from ESS) using the LMS in the universe of almost 500 teachers in the university. On the other hand, Panopto, which can be used by teachers and students, has at this time 1092 users. These numbers show that the adoption of technological tools is low, and it is important to know and to understand the reasons that are conditioning the effective adoption of the technologies at UTAD, by the academic community, considering the continuous effort in providing innovative electronic services to both students and professors (Borges, Justino, Gonçalves, Barroso, & Reis, 2017; Borges, Justino, Vaz, Barroso, & Reis, 2017; Borges, Vaz, et al., 2017) as well as to have a sustainable policy toward supporting universal access to electronic services for all users (Reis, Barroso, & Gonçalves, 2013; Reis et al., 2017).

UTAD takes part of a consortium between three Portuguese universities—the University of Porto (UP), the University of Minho (UM), and the University of Trás-os-Montes e Alto Douro, called UNorte.pt. Consortium (UNorte.pt). It was created in 2015, with the aim of allowing the deepening of the strategic articulation between these institutions.

The UNorte.pt. has the goals of strategic and operational coordination in areas such as (1) medium-/long-term institutional objectives, with identification of areas of cooperation and joint action; (2) educational offer promoting joint projects, especially in areas of emerging training or low demand; (3) platforms and the production of contents for distance education and online courses; (4) student mobility; (5) research, either by strengthening critical mass or by complementing existing resources and projects; (6) sharing of human resources for teachers, researchers, and non-teachers; (7) active and concerted participation in the implementation of regional and transregional strategies, which should be in line with institutional strategic plans, without neglecting the potential involvement of other higher education institutions in the region and other public and private entities; (8) the joint international promotion of the Northern Region as an area of higher education for reference and for research and development of excellence, including joint actions to attract foreign students and researchers; (9) promotion of academic entrepreneurship; (10) the investment in areas of common interest such as databases or scientific infrastructures; (11) joint representation in transnational networks; (12) promotion of university sports, including the joint organization of major international events; (13) school social action; and (14) organization of cultural initiatives.

UP and UM are institutions with consolidated practices of use of ICT in educational activities. The exchange of knowledge between the partners of UNorte.pt. allows UTAD to learn from its partners' know-how and develop the use of distance learning and b-learning practices within its courses.

Within the scope of this consortium, the UnorteX.pt project is under implementation and aims the development in the three partner institutions of a common architecture for distance education, training and development of resources, and local technical teams to develop distance training courses and support teaching, such as the creation of two multimedia recording studios and the creation of certified rooms for online exams in each institution. The UNorteX.pt. also foresees the creation of rules of accreditation of distance education common to the three institutions.

Data Collection

The study presented in this paper reflects UTAD's context. The empirical work is based in a questionnaire that was created and applied, allowing to assess teachers' needs and expectations regarding the ICT adoption in their pedagogical practices.

The questionnaire is based on a literature review about the theme and has in consideration the work developed until now, related to the topic under discussion. The survey was designed to determine (a) attitudes regarding the use of education support technologies (Group 2), (b) self-trust perceived in the integration of education support technologies (Group 3), and (c) environment and institutional support (Group 4). Group 1 was about respondents' profile characterization, with three closed questions (age, gender, and UTAD's school where they belong). Group 2 is composed of 14 affirmations to be classified in 5-point Likert scale. Group 3 has six affirmations to be classified in 5-point Likert scale. Group 4 is composed of seven questions. The first one of the group has nine affirmations to be classified in 5-point Likert scale. The second, the third, the fifth, and the sixth ones are multiple-choice questions, related to the software, support mechanisms, and initiatives made available by the university to promote the adoption of ICT. And the fourth and seventh are open questions, not obligatory.

During July 2017, the questionnaire was conducted online, in a survey platform made available by UTAD, the LimeSurvey platform. It was anonymous and was accessible through a link sent by email to teachers. After reaching the number of answers corresponding to about 25% of the total university teachers, the results were analyzed, and the results are presented below.

Findings

Ultimately, 163 teachers began the survey, and 125 teachers (approximately 25% of UTAD faculty) completed it. The 38 incomplete answers were not considered to the analysis.

The respondents are mostly male (71), corresponding to 62% of the total, having 43 women responded to the questionnaire, representing 38% of the total of respondents. The majority of respondents are from ECT (33, which correspond to 26% of the total) and ECAV (30, 24% of the total of respondents) schools (Fig. 9.1).

Current Use of ICT Tools

Teachers have identified the tools they use from the ones available at UTAD (Table 9.1). SIDE is the most known and used, followed by Scientific Repository and Moodle. This is due to the obligation of using SIDE to course management and

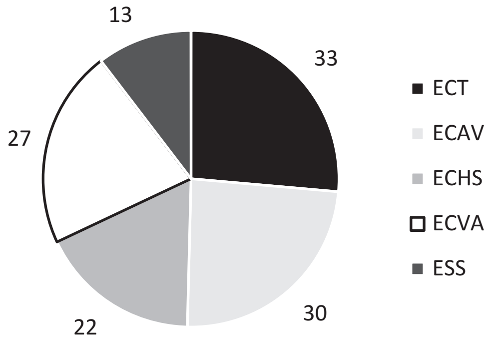

Fig. 9.1 Graphic with distribution of the respondents by school of teaching in UTAD

Table 9.1 Answers to questions related to the knowledge and use of software provided by the university to support teaching and learning processes

	Tools that teachers know		Tools that teachers use	
Tools	Users answers	%	Users answers	%
SIDE	**111**	**97%**	**110**	**96%**
Moodle	**73**	**64%**	**31**	**27%**
Panopto	**16**	**14%**	**5**	**4%**
Colibri	38	33%	24	21%
Scientific repository	**87**	**76%**	**67**	**59%**
Educast	9	8%	2	2%
Survey platform	61	54%	36	32%

Scientific Repository to share with UTAD's academic population the scientific publications produced.

It is important to see that the number of teachers knowing Moodle is much higher than the number of teachers using it.

Panopto is a tool for streaming and allows to produce multimedia content. It has been available at the university for about a year, and from the answers to the questionnaire, it is possible to conclude that it is not known by most teachers, being a very small percentage that makes use of it.

Something similar happens with Educast and Colibri, tools for videoconference purposes, and these are available at UTAD for at least 5 years.

Teachers were asked to identify other tools they use for educational proposes, besides the ones made available by the university, and they named tools as Google Drive, YouTube, Skype, Facebook, Diigo, and Cmap, among others. These tools are free software available in the Internet, some of them with the same purposes as the ones available at UTAD. For example, Panopto is a multimedia repository, like YouTube. On the other hand, Educast and Colibri can be used to make streaming of live events with the possibility of interaction between the participants, as Skype does.

Attitudes Regarding the Use of ICT Tools to Support Teaching

Analyzing the distribution of answers from teachers to questions related to their attitudes regarding the use of ICT tools to support teaching (Fig. 9.2), it is possible to conclude that in general, teachers are comfortable with the use of technologies in an educational context, identifying them as allies in the teaching and learning processes.

Although the great majority affirm that they are comfortable with the technologies in the process of teaching, there are still some that manifest the contrary feeling. A similar majority believes that technologies are valuable in supporting teaching while affirming that they can help teachers to teach more effectively, as well as they can be conducive to students' learning process.

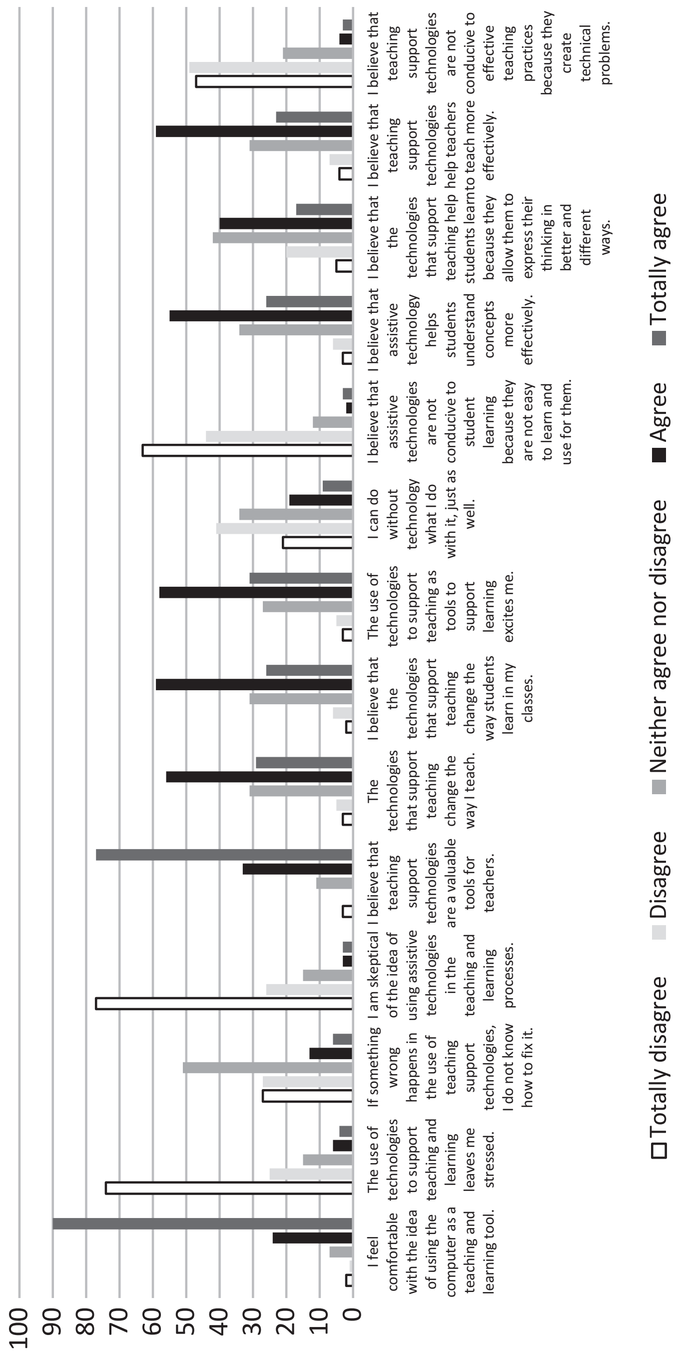

Fig. 9.2 Graphic with distribution of answers to questions about attitudes regarding the use of ICT tools to support teaching

Most are confident in their ability to solve any problems that arise in using technologies for teaching. However, they are not consensual about the possibility of doing without technology what they do with it, equally well.

Perceived Self-Trust in the Use of ICT Tools

Teachers' answers to questions related to their perceived self-trust in the use of ICT tools (Fig. 9.3) showed that in general they are confident in the use of technologies in their teaching practices. The major part of respondents affirm that they are able to plan and develop teaching and learning activities using ICT tools, choosing software, and guiding their students in the use and/or selection of tools for the tasks.

The email is the tool that teachers clearly identify as the one they use in a more comfortable way.

Current Needs and Expectations for ICT Adoption

In an attempt to know and understand teachers' needs and expectations regarding the institutional reality of ICT integration in educational practices, several situations were described, so the respondents could identify the ones that they have already been part of and the ones they know about.

Through the results presented in Fig. 9.4, it is possible to conclude that the lack of knowledge of teaching practices among teachers is an obvious reality. This may be due to the lack of communication regarding the topic of ICT adoption in educational practices, made clear by respondents when asked about moments for sharing and discussing ideas and routines of ICT use.

Results on Fig. 9.4 make it possible to verify that a high number of teachers are not aware of institutional initiatives to support ICT adoption in education or never appealed to them, so they cannot classify them as adequate or not. Likewise, it is possible to verify that a relevant number of those who know the initiatives developed consider them inadequate or insufficient to give the desired answer to the problem, both in the technological and pedagogical aspects.

Focusing on the initiatives undertaken by UTAD to support ICT adoption in educational practices, we tried to explore teachers' knowledge about them. As Table 9.2 shows, the better known is the existence of a "technical and pedagogical support team." Even so, only 59% of respondents are aware of the existence of this support team. The same applies to knowledge about training courses and workshops on ICT in education. UNortex.pt. project is practically unknown to respondents.

When asked about different initiatives where they would like to participate or promote in UTAD, teachers opted for the training, namely, continuing education courses in e-learning (Table 9.3). Almost in the same proportion, they chose the workshops on technical aspects of handling tools to support teaching.

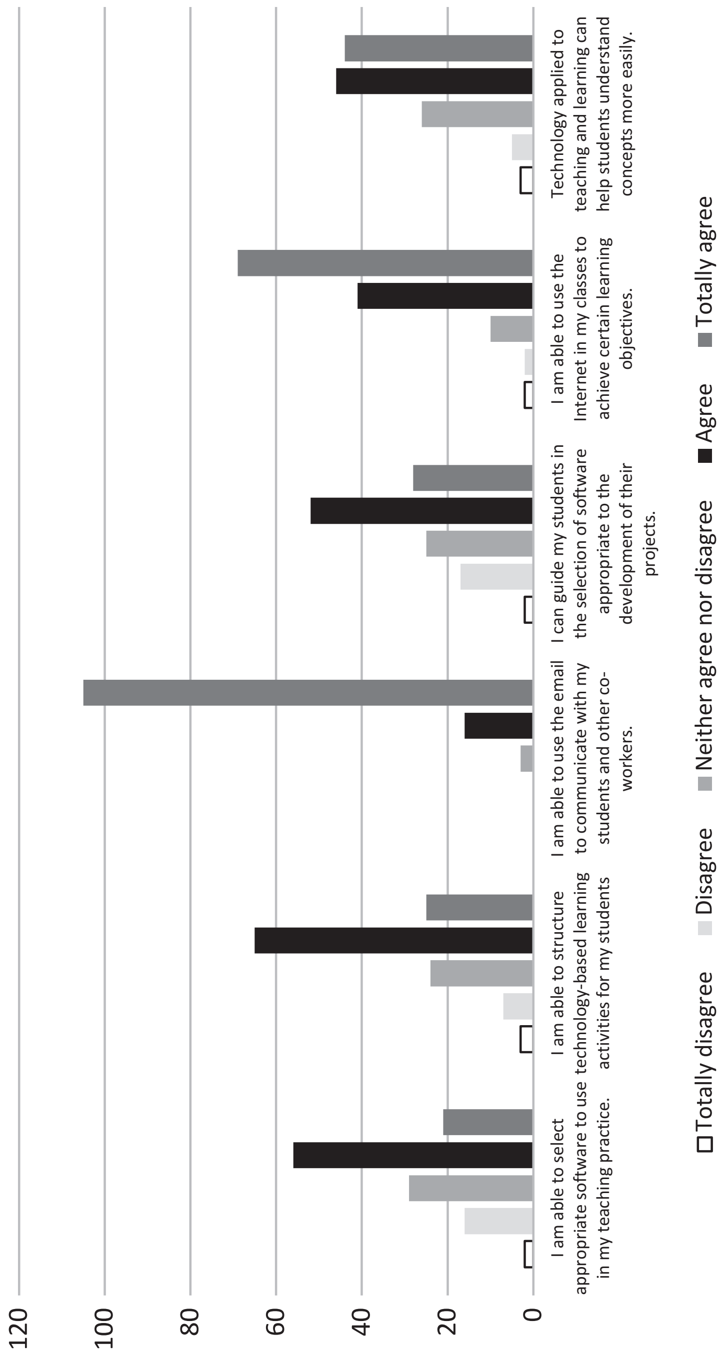

Fig. 9.3 Graphic with distribution of answers to questions about perceived self-trust in the use of ICT tools

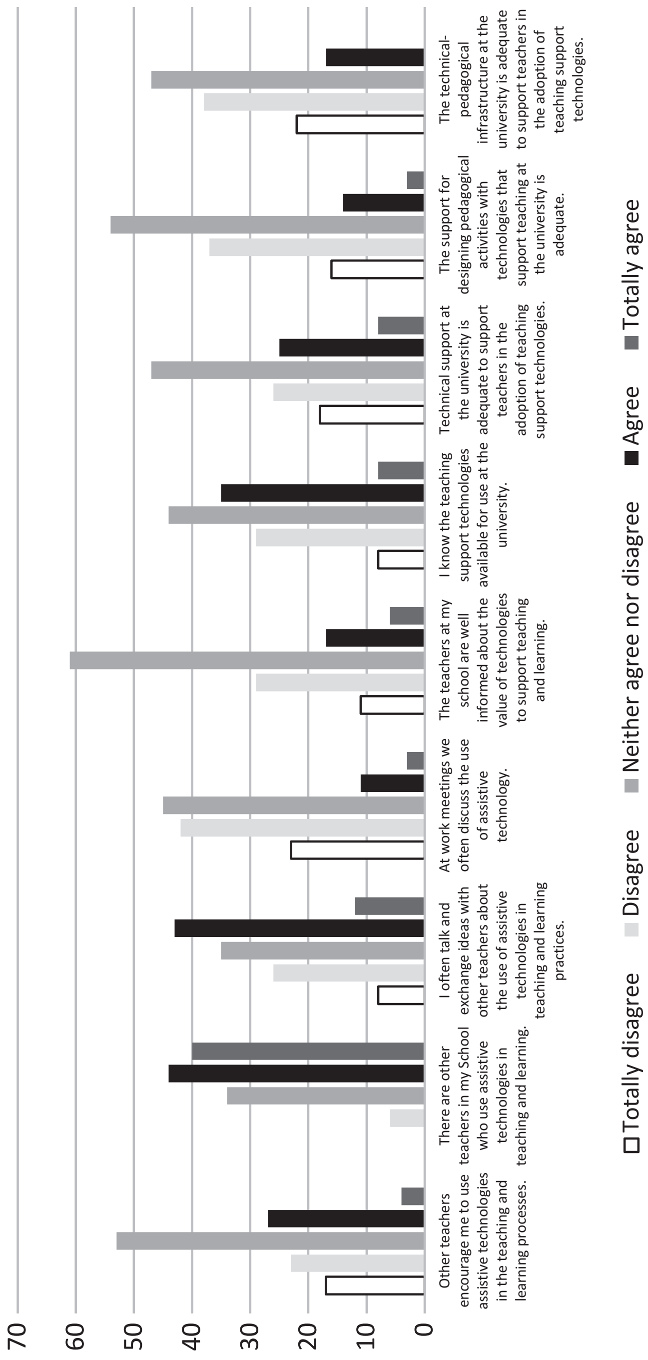

Fig. 9.4 Graphic with distribution of answers to questions about perceived self-trust in the use of ICT tools

Table 9.2 Answers about the initiatives teachers know about, promoted by UTAD to ICT adoption in teaching and learning processes

Initiatives	Users' answers	%
Technical and pedagogical support team	**67**	**59%**
Production of multimedia resources	40	35%
UNortex.pt project	9	8%
Training courses and technical workshops	**57**	**50%**

Table 9.3 Answers to question about the initiatives teachers would be interested to participate or promote at UTAD, related to ICT use with educational proposes

Initiatives	Users' choices	%
Short-term training courses in e-learning, for a varied public (civil servants, specialists, students, etc.)	49	43%
Continuing education courses in e-learning (for teachers)	**66**	**58%**
Massive and open online courses (MOOCs)	32	28%
Workshops on technological tools	**64**	**56%**
Workshops for the design, development, and evaluation of e-learning activities	47	41%
Production of multimedia content	60	53%
Research projects related to teaching supported by technologies	31	27%
Inclusion of teaching support technologies in the curricular units	**61**	**54%**
Preparation and implementation of training courses (MOOCs, continuous training, or others) as a way of disseminating the results of funded projects	21	18%

More than half of the respondents are open to inclusion of teaching support technologies in the curricular units and production of multimedia content.

Conclusions

The results from the questionnaire show that the adoption of ICT by teachers at UTAD is yet lower than the desirable, although teachers have demonstrated interest in developing their know-how and capabilities in the use of ICT in their teaching practices.

The results of the study allowed to identify limitations in the process of dissemination of the adoption of ICT in educational processes, namely, at the level of (a) communication and dissemination of the tools and services provided by the university to support this process and (b) dissemination of initiatives implemented for the promotion of the use of technologies in teaching support.

Key conclusions include the need to adequately develop an infrastructure that facilitates ICT adoption, as well as the need to provide technical and pedagogical training to facilitate ICT use and the transformation of face-to-face courses to mixed-mode experiences, in a way that integrates the best elements of in-person and online learning. On the other hand, it is important to provide adequate ongoing technical and pedagogical support for teachers.

Based on the findings of this study, UTAD has already designed its action plan to promote a more effective and efficient adoption of ICT by teachers. And it is already being implemented. Keeping in mind the importance teachers may likely place on group communication, training, and on suitable pedagogical and technological support, the plan is focused on these three strands to be explored. On the strand related to communication and dissemination of measures developed, are being released visits for presentation in person of the support team for ICT adoption, in each school of UTAD, with the presence of the school director and invited teachers.

The strand related to training is being explored with the completion of different training courses for teachers. The first is happening this September, 2017, as an online training course, about Moodle and Panopto as supporting tools of the educational processes, counting already with 80 enrolled teachers.

In addition, recently UTAD has established an agreement with MiriadaX platform (http://miriadax.net/) for massive open online courses (MOOCs), adding another tool to the range already available, and making possible to reach new audiences through the possibility to perform this type of courses.

It is already possible to identify results from the implemented measures, such as the two MOOCs in preparation, authored by UTAD teachers, one on digital accessibility and the other on sustainable tourism. The technical and pedagogical support has been requested for the planning and development of these courses. On the other hand, several teachers of different scientific areas are starting to develop multimedia content to be part of an online component of their classes, in collaboration with the supporting team for ICT adoption.

As future work, there is the creation of the new infrastructures foreseen by the project UNorteX.pt, namely, the multimedia studios and the certified room of online exams, in addition to the ongoing work on the inter-institutional accreditation component among the consortium partners.

As a result of this study, we hope universities may continue the efforts to facilitate ICT adoption by faculty, improving their effectiveness in teaching and learning process with these tools. To achieve that, higher education institutions may consider the factors identified as barriers and facilitators of the process, namely, the ones related to teachers' motivation and attitudes regarding the use of ICT.

This is a topic that needs to be continually explored in order to give adequate answer to incoming problems. Future research could include interviews with teachers at different levels of ICT adoption in their practices regarding their experiences and pointing out particular measures as facilitating or impeding their ICT adoption in teaching processes.

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Chapter 10
Hostage of the Software: Experiences in Teaching Inferential Statistics to Undergraduate Human-Computer Interaction Students and a Survey of the Literature

Frode E. Sandnes and Evelyn Eika

Introduction

Null hypothesis significance testing can be a powerful mechanism for analyzing empirical data, yet it can also be highly misleading when applied incorrectly (Nickerson, 2000). Several voices echo the challenges of making statistics interesting and relevant to students (Gordon, 2004; Phua, 2007), especially when these students are nonspecialists (Yilmaz, 1996). Several pedagogical strategies have been applied to the teaching of statistics such as small group collaboration (Garfield, 1993), problem-based learning (Bland, 2004), the use of practical examples (Chermak & Weiss, 1999; Smith & Martinez-Moyano, 2012), and distance and virtual education modes (Gemmell, Sandars, Taylor, & Reed, 2011; López & Pérez, 2005).

Many study programs in engineering and especially computer science include some courses on statistics. These courses are often taught by mathematicians, statisticians, or physicists and often focus on the mathematical sides of statistics. The mathematical angle is indeed valuable and applicable to many areas of computer science. However, the more practical sides of statistics such as inferential statistics that concerns itself with hypothesis testing are also increasingly relevant. Traditionally, inferential statistics has been more visible in the curriculum of other fields of study such as agriculture, where one compares crops, medicine, and health sciences (Howlett & Phelps, 2006) and where one may compare the effects of

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treatment, psychology, education (Jian, Sandnes, Huang, Cai, & Law, 2008; Jian, Sandnes, Huang, Huang, & Hagen, 2010a), educational policy (Jian, Sandnes, Huang, & Huang, 2010; Jian, Sandnes, Huang, Huang, & Hagen, 2010b), language learning (Brown, 2013; Jian, Sandnes, Huang, Law, & Huang, 2009), linguistics (Eika & Hsieh, 2017; Jian, 2015a, 2015b), and social science (Cronin & Carroll, 2015), to name a few.

Inferential statistics has been absent in the curriculum of many engineering, and computer science, study programs. This is because traditional computer science and engineering have utilized different research methods, which do not require inferential statistics. Typical tasks include measuring differences based on deterministic processes, for example, the timing of computer program execution and success rates such as detecting object in images (Huang, Chang, Chen, & Sandnes, 2008) and in video (Huang, Hsu, & Sandnes, 2007). Other measurement types include the accuracy of computation, such as that of geo-localization based on information in images (Sandnes, 2009) and geolocation based on light intensities (Sandnes, 2010a), shadows (Sandnes, 2011), or underwater light intensities (Gómez, Sandnes, & Fernández, 2012). Engineering research often also simply involves demonstrating the workings of a new engineering solution, for instance, demonstrating that reliable information transfer is possible via paper (Huang, Chang, & Sandnes, 2010).

Our experience is that practical knowledge and appreciation of inferential statistics are generally low among staff in such programs, even among the statisticians. This may be because computer science has traditionally focused on systems and algorithm. When such systems or algorithms are measured under controlled conditions, they give very similar or even identical results each time. Inferential statistics has therefore not been considered a particularly useful or relevant methodology. However, with the emergence of more multidisciplinary topics in computer science and engineering, such as human-computer interaction, ICT in education, and the merging of ICT and health, the need of inferential statistics has emerged as it involves measuring human behavior, which is highly variable. We share our objectives with Peiris and Peseta (2012) who promoted the introduction of effective statistical tools to students early during their undergraduate studies.

Human-Computer Interaction

Human-computer interaction (HCI) has emerged in the curriculum of many computer science study programs during the last decade. HCI can be considered the study of all phenomena related to the interaction between human and machine. HCI is a multidisciplinary field that relies on a range of research methodologies. We have focused on HCI generally and design for all specifically (Whitney et al., 2011). One may consider the research method a tool where one needs to choose the most suitable tool for a given problem. Examples from our own human-computer research lab include the use of traditional computer science techniques in HCI such as graph theory (Sandnes, 2005), heuristic evaluation (Berget, Herstad, & Sandnes, 2016; Sandnes, Jian, Huang, & Huang, 2010), qualitative research methods based on interviews (Sandnes, 2016a) and text analysis (Eika, 2016; Eika & Sandnes, 2016a), visualization (Eika & Sandnes, 2016b; Sandnes, 2016b, 2016c), as well as design and development. Design includes sketching in 2D (Sandnes & Jian, 2012) and 3D (Sandnes, 2016d, 2016e), 3D modelling (Sandnes, 2017), design of concepts such as new interaction styles for self-service kiosks (Hagen & Sandnes, 2010), collaborative work (Hagen & Sandnes, 2012) and volunteering (Chen, Cheng, Sandnes, & Lee, 2011), tactile feedback for pedestrians (Lin, Cheng, Yu, & Sandnes, 2008), design of devices such as augmented reality displays (Sandnes & Eika, 2017b), and the development of new design methods (Sandnes, 2015).

Examples of exploration through development include new interaction techniques such as wheel controls (Sandnes & Huang, 2007), human behavior monitoring based on touch dynamics (Sandnes & Zhang, 2012), new color design tools that support human contrast perception (Sandnes & Zhao, 2015a, 2015b), physical navigation tools for blind users using radar (Gomez & Sandnes, 2012), and virtual navigation in static panoramic views (Sandnes & Huang, 2016). Common to these studies is that they allow a new idea to be tried by building working prototypes. The focus is often not on the testing of the final results, but rather on the discovery over various technical challenges on the way and how these can be solved.

Inferential statistics is indeed also a highly relevant methodology in human-computer interaction. However, the degree to which the focus is placed on qualitative or quantities methods seems to vary as many human-computer interaction courses are purely qualitative. We have taken a balanced approach introducing the students to a wide range of methods, including inferential statistics. Typical examples of quantitative problems studied by students and staff in our lab include comparative studies of dyslexia (Berget, Mulvey, & Sandnes, 2016; Berget & Sandnes, 2015, 2016). Such studies often compare two groups, namely, dyslexic participants and a control group, and therefore often rely on paired *t*-tests. *T*-tests are also used in other studies of cognitive aspects of interaction involving two groups (Sandnes & Jian, 2004; Sandnes & Lundh, 2015) and studies involving users with and without vision (Sandnes et al., 2012) or when comparing two keyboard layouts (Sandnes, 2010b) or left-right interaction directions (Sandnes, Thorkildssen, Arvei, & Buverad, 2004). Text entry experiences such as those involving new interaction styles often rely on repeated measures of ANOVAs as there are often more than two levels per factor or more factors (Sandnes, 2008; Sandnes & Aubert, 2007). Often text entry experiments require learning, such as chording (Sandnes & Huang, 2006a, 2006b), and the learning effects are studied over time through various sessions (Sandnes, 2006). ANOVA is thus often a suitable tool in such cases.

Challenges of Learning Statistics

Pedagogical Strategies

There are different pedagogical approaches to teaching statistics ranging from the very mathematical and theoretical to the very practical. Theoretical approaches usually evolve around lectures, while the practical approaches focus on learning by doing through assignments and coursework. The mathematical approach is common as it is simple and justified by the argument that students should fully understand the underlying principles. There appears to be a belief that good mathematical skills are essential for learning statistics. However, Galagedera, Woodward, and Degamboda (2000) found that perceived mathematical abilities have little effect on students' performance in elementary statistics. Much of the literature seems to favor practical approaches over theoretical approaches where students learn through practice. Marson (2007) collected empirical evidence to support that the three key elements that lead to successful teaching of statistics include repetition, immediate feedback, and the use of real data.

Teacher Qualifications

Teachers are essential to the successful teaching of statistics (Petocz, Gordon, & Reid, 2006). Several studies have pointed to the fact that statistics often is taught by non-statisticians with a lack of basic statistics knowledge (Dabos, 2016) or with misconceptions about statistics (Haller & Krauss, 2002). In our view, the teacher must have a good grasp of statistics but even more important in the context of applied experimental design is that the teacher has practical working experience with empirical experiment and analysis, perhaps from their own research. It is our opinion that it is not enough for a teacher to have a sound understanding of theoretical statistics without experience from actual empirical research. The preference for more practical and simple procedures over mathematical elegance is also echoed by Wood (2001, 2002) and Khait (2004), among others.

Learning Resources

We have found that until recently there have been very few suitable textbooks and learning resources available. Most resources focus on the mathematical sides, and few give practical advice that is relevant for empirical research. Gliner, Leech, and Morgan (2002) surveyed several statistics textbooks and found that none of them contributes to removing common misconceptions about null hypothesis significance testing. Fortunately, the situation is gradually changing with the emergence of relevant textbooks such as (Mackenzie, 2013) and various online learning resources.

Statistics Software

Computer-assisted instruction has been shown to have a positive effect in statistics teaching (Basturk, 2005). However, a key challenge has been the lack of suitable statistics software. There is a vast number of commercial software packages on sale such as SPSS, SAS, STATA, etc., with SPSS being one of the market leaders. One main challenge with SPSS is the high cost, making it financially unrealistic to acquire for many higher education institutions with limited budgets. SPSS and other commercial software have also been criticized for being undemocratic in the sense that the internal algorithms are not open for scrutiny. Open-source software is hailed as giving the users an opportunity to investigate the correctness of the underlying statistical algorithms. From our experience, the complexity of SPSS is the largest challenge. It provides a huge amount of functionality, and it can be very daunting to navigate the menus for a novice. SPSS is considered easy to use once one has learned its use and knows some statistics and which tests one needs. It is undoubtedly hard to use for beginners who in addition are insecure about which tests to apply for a given problem. The many YouTube instruction videos for basic operations are testaments to this. Simple functions are hidden behind obscure menus. For instance, to conduct a Friedman test for nonparametric repeated measures analysis of variance of three groups, one needs to go to the analysis menu (which is quite long), select nonparametric tests, and select legacy tests and then K-related samples. This path is easy to remember but nearly impossible to discover for beginners. Each test is associated with several complex dialogues with the various options hidden behind various buttons (hidden functionality). Moreover, the results appear in a separate output window, and it can be hard for users to connect their actions with the displayed output.

The open-source landscape is dominated by R-project (Crawley, 2012). R-project is a comprehensive and powerful statistics package which is relatively easy to use, despite its being command-line based. There are also several open-source GUI alternatives for R (Snellenburg, Laptenok, Seger, Mullen, & Van Stokkum, 2012), and R is easily extended through scripting and is thus popular with programmers. The main problem with R-project is that repeated measures analysis of variance is quite inaccessible. It is possible to perform such tests, but it is not straightforward to set up such tests without in-depth statistical knowledge.

For several years we used Excel for the introduction to hypothesis testing as well as course management (Sandnes & Eika, 2017a). The advantages of Excel are that it is commonly available, although it is not open source. We have used the Analysis ToolPak that contains *t*-tests, one-way and two-way ANOVA, and regression analysis. Our experience is that the most challenging aspects of using Excel are for students to correctly interpret the results as the output is verbose. One major drawback with Excel is that it does not provide repeated measures ANOVA, which is essential for human-computer interaction as it most often involves within-subject designs. Note that it is possible to perform a rudimentary one-way repeated measures analysis using the two-way ANOVA function with subjects as one factor. There are, however, several extensions available for Excel, such as Charles Zaiontz's comprehensive statistics tools for Excel (Zaiontz, 2017). Regrettably, the security policy of our university does not allow students and teachers to install third-party macro packages in Microsoft Office on university machines. Various versions of Excel have also been criticized during the past two decades for inaccurate computations, including Excel 97 (McCullough & Wilson, 1999), Excel 2003 (McCullough & Wilson, 2005), Excel 2007 (McCullough & Heiser, 2008; Yalta, 2008), and Excel 2010 (Mélard, 2014).

In our teaching, we have started to use JASP (Jeffrey's Amazing Software Package) (Marsman & Wagenmakers, 2017), a relatively young statistics software package developed at the University of Amsterdam (see Fig. 10.1 for an example screenshot). Note that JASP is different from the project of the same name (Java-based Statistics Processor (Nakano, Yamamoto, Kobayashi, & Fujiwara, 2014) from two decades ago). JASP is based on R-project but presents the functionality through a simple and streamlined user interface that only exposes the most important functionality needed in introductions to inferential statistics, such as paired and independent *t*-tests, ANOVA, repeated measures ANOVA, correlation, and factor analysis. The ANOVA analysis functionality is especially useful as it supports multiple factors and mixed designs (within- and between-group factors) in addition to several post hoc tests such as Tukey, Scheffe, Bonferroni, and Holm-Bonferroni. Normality testing and other assumption tests are also available via the user interface. The number of options is also streamlined, making the perceived impression of simplicity. The output is also minimalistic, only displaying essential information. It changes dynamically as the users alter the configuration of the statistical tests. This overall software appears non-threatening and invites exploration. Moreover, its structure promotes correct use of statistical tests. The main drawback of JASP is the lack of nonparametric tests for more than two groups.

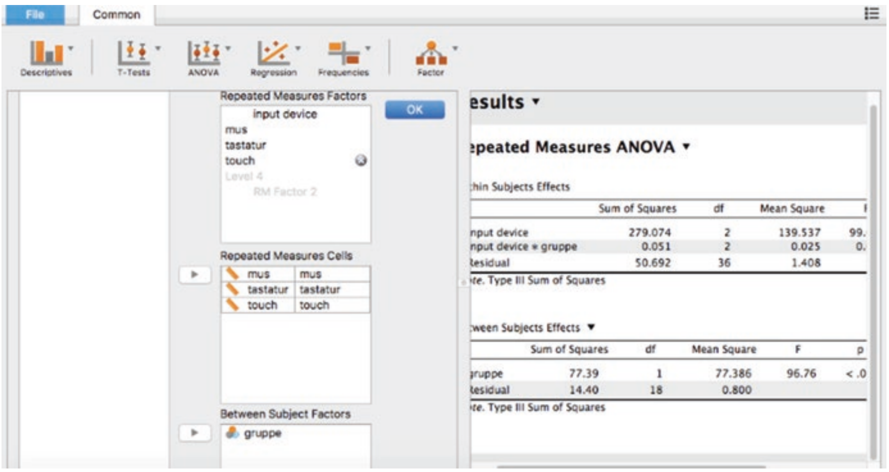

Fig. 10.1 JASP user interface (mixed ANOVA view)

Statistical Concepts

Students struggle with several issues when learning inferential statistics. Sotos, Vanhoof, Van den Noortgate, and Onghena (2007) gave a comprehensive review of common statistics misconceptions among students in various disciplines. Our experience is that the statistical notation appears cryptic and it is hard to understand the meaning of the various values listed, that is, the statistics for a given test, degrees of freedom, and the *p*-value. Students' conceptions and misconceptions of the *p*-value have been studied in detail by Reaburn (2014), Wagenmakers (2007), and others.

It is also challenging to connect the shorthand notation in scientific papers with the values that appear in the statistics software. Further, many students are very uncertain about how many observations are needed. Normal distribution is another issue. Normality is often one of the core assumptions of the parametric tests. Another issue students struggle to grasp is the necessity of using an ANOVA test on all levels of the factor under investigation instead of just running a *t*-test on the combination of pairs of levels. This challenge is also reported for papers published in medical journals (Skaik, 2015; Wu et al., 2011). Students also struggle with understanding the need to use repeated measures ANOVA instead of an ordinary ANOVA when dealing with within-subject designs. In human-computer interaction, within-subjects designs are probably the most common; it is easier to execute as fewer participants are needed. In agriculture, on the other hand, within-subjects designs are usually not possible, and most studies are employing between-subject designs relying on basic ANOVA.

One of the largest challenges is selecting the correct statistical test given a specific problem. Many different tests were named after various people, which could be daunting for a beginner, yet quite recognizable for someone with some experience with empirical experimentation statistics. Examples include Wilcoxon, Mann-Whitney, Friedman, Kruskal-Wallis, etc. The connection of applying tests with strange names under certain circumstances may seem to be a bit of black magic to students. Unless one is using a full statistical package such as SPSS, or R-project, students may not actually have access to all the tests and therefore may choose a *t*-test or ANOVA as these are more easily available.

One recent textbook on experimental design (Mackenzie, 2013) avoids *t*-tests altogether by analyzing two samples with an ANOVA test or a repeated measures ANOVA test. Indeed, the *t*-test can be replaced by an ANOVA test, and students will then not use *t*-tests incorrectly by doing pairwise comparisons, a problem found in scientific papers as well (Skaik, 2015; Wu et al., 2011). However, it is our opinion that when reporting an experiment with a *t*-test, the use of the *t*-test gives vital information to the reader about the experimental design. The use of *t*-tests is also an experimental convention when comparing two groups. We have opted for teaching the *t*-tests despite the risk of it being used incorrectly.

Our experience is also that students find it challenging to differentiate between when to use nonparametric tests and parametric tests. The assumption of normality is well known, but there are also other assumptions for various tests, such as homogeneity and sphericity that are less obvious. Moreover, the simple notion of considering the data type of the dependent variables is often ignored. It is recommended that interval data are used with parametric tests, and ordinal, categorical, and dichotomous (binary) data are used with nonparametric tests.

When the data suggest a nonparametric test, it may seem confusing and frustrating to students when there are actually no obvious standard tests available, e.g., a mixed multifactor designs. The many questions posted on various discussion groups are testaments to this challenge. It has also been found that many scientific papers incorrectly report parametric tests when the data suggest nonparametric tests (Yim, Nahm, Han, & Park, 2010).

Experimental Design

Some students struggle with practical experimental issues that affect the statistical analyses. These difficulties include ensuring that the presentation order is varied in within-subject designs, recruiting enough participants, having sufficiently long session to get reliable measurements, and running a pilot to ensure that experimental setup is working as expected.

Based on our experiences with teaching statistics to undergraduate students over several years, we have developed a simple pedagogical framework with the specific goal of improving the quality and validity of the statistical analyses carried out by the students. Our framework is discussed in the subsequent sections.

A Toolbox Approach to Inferential Statistics

The human-computer interaction course is offered to second year undergraduate students (3-year study programs). It is attended by students with a comprehensive mathematical background (computer engineering students) and those with a minimal amount of mathematical background (applied computer science students). It is also attended by students from other fields including library and information science, archival science, etc. The inferential statistics constitutes approximately 1/6 of the total syllabus in terms of lectures (approximately 2 weeks), yet it takes up 1/3 of the students' work (1 out of 3 graded project works). Inferential statistics was introduced into the curriculum for about 10 years, and it was mostly based on Excel until the emergence of JASP. Quite some time is spent motivating the students for learning inferential statistics with arguments for why it is important and when it is applicable.

When the students were first introduced to statistics, they had to relate to an overwhelming number of issues at once, such as various statistical tests with odd names, various constraints and assumptions, obscure notation, complex software, and unfamiliar terminology. The key to our pedagogical approach is to treat the statistical tests as measurement tools from a toolbox where the data are the input and the *p*-value is the output value of importance. We have used a needle instrument metaphor to help students build a mental model of how to interpret *p*-values (see Fig. 10.2). The needle is a universal symbol of quantity and limit. When the needle is on the left-hand side of the red bar, there is significance (usually difference); when it is on the right red bar, there is no significance. The left side of the red arc marks the significance level, which is usually 0.05 unless some correction is used such as Bonferroni or Holm-Bonferroni.

The focus is on the use of the tools and not how they work. The internal mathematical and algorithmic workings are omitted completely. It is an explicit goal not to include any mathematical expressions at all in the course material, besides the *p*-value inequalities.

A central part of the framework is also to train statistical literacy in the sense of being able to read and comprehend the terminology and notation found in various scientific papers. Extracts from scientific papers are hence used in the teaching. Students are also encouraged to search for and read literature for their assignments. Within the area of human-computer interaction, a great number of research papers can be read by undergraduate students as these are relevant to phenomena of user interfaces that the students are already familiar with. Good sources include proceedings from ACM SIGCHI conferences, ACM ASSETS, etc. The goal is to reduce anxiety associated with the unfamiliar coding of the standard notation and build students' confidence in interpreting the notation. Students who can decode the notation are probably also more likely to correctly encode the notation. Next, experiences from reading research papers are intended to help illustrate the purpose and use of the notations in practice. To help students, we employ simple summary sheets such as the one shown in Fig. 10.3.

The framework also relies on a map of statistical tests (see Fig. 10.4) that gives an overview of the tests covered inspired by an overview presented by McCrum-Gardner (2008). The horizontal dimension signals the data type of the dependent variable, and the vertical dimension signals the organization of the dependent variables and the experimental design. Clearly, the diversity of statistical tests and special cases is too large to be captured by a simple sheet of paper, and we thus focus on the most commonly needed cases.

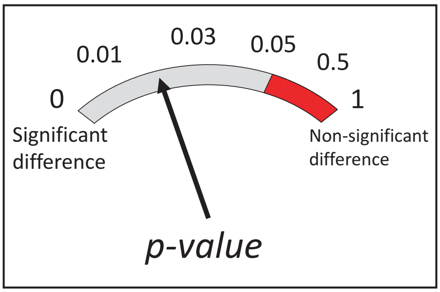

Fig. 10.2 Using a needle instrument metaphor for helping students to build a mental model for how to interpret the *p*-value

symbol(value) = value, ***p*** = value

example	Test
t(38) = 2.428, ***p*** = .020	t-test
Z = -1.807, ***p*** = .071	Wilcoxon
F(2,27) = 4.467, ***p*** = .021	ANOVA
χ2(2) = 7.600, ***p*** = .022	Chi-squared
r(15) = -.918, ***p*** = .001	Pearson's
r_s(15) = -1.0, ***p*** = .001	Spearmann
H = 14.338, ***p*** < .01	Kruskal-Wallis
U = 67.5, ***p*** = .034	Mann–Whitney U-test

Fig. 10.3 Notation and notation pattern reference sheet for common tests

Visualization is used extensively to illustrate the various concepts such as experimental designs. For example, Fig. 10.5 illustrates an example of a mixed design with one within-subjects factor (input device) with three levels (keyboard, mouse, and touch) and one between-subjects factor with two levels (male and female). The essence of the diagram is that each participant is exposed to all the within-group factors, while different participants belong to only one between-group factor. Since the same participants occur in several (within) groups, a repeated measures ANOVA is needed.

We use the JASP software to show examples in class and recommend students to use JASP for their assignments. However, it is not a requirement, and students are free to employ the statistical tools of their choice.

Typical experiments that have been given to the students include finding empirical evidence of what gives the best performance of keyboards with alphabetical and qwerty layout, digit input with numeric keypad versus the number keys on normal qwerty keyboards, and what type of date input technique works best on web pages. For more common phenomena, the students must design the test environments; for more specialized cases such as scanning keyboards, the students are provided with basic code which they can tailor to their particular needs. More recently we have also experimented with free projects where the students themselves must propose a phenomenon they want to explore by conducting an experiment where they collect data that are analyzed using inferential statistics.

In addition to the challenges discussed, we have found that some students are uncertain about whether to include all raw observations in the test or whether to use a representative aggregated value for each participant/session (such as a mean performance score). Most students seem to grasp the idea of measuring performance. However, measuring error rates appears to be difficult in practice. In particular, how does one define what is meant by an error for a given problem? Also, it is quite common for students to make errors in the experimental setup which they discover after completing the project. Such errors, nevertheless, may provide learning opportunities.

		parametric	Non-parametric		
Category	Experiment type	Interval data	Ordinal and interval data	Nominal data	Dichotomous data
Independent measurements	Two groups	t-test	Mann–Whitney U-test	χ2-test for 2 × C table	χ2-test for 2 × 2 table (Fisher´s exact test (N < 20)
	Three or more groups	One-way ANOVA	Kruskal–Wallis one-way ANOVA	χ2 -Test for R × C table	N/A
	Three or more groups, multiple factors	Two-way, three-way, … ANOVA	None	None	None
Repeated measurements	Two groups	Paired t-test	Wilcoxon signed rank test	McNemar’s test	McNemar’s test
	Three or more groups	Repeated measures ANOVA	Friedman’s test	Cochran’s Q	None
	Three or more groups, multiple factors	Multi-factor repeated measures ANOVA	None	None	None
Mixed design	Two or more groups	Mixed design ANOVA	None	None	None
	Two or more groups, multiple factors	Multifactor mixed design ANOVA	None	None	None
Association	Correlation	Pearson’s	Spearman’ s rank	N/A	N/A

Fig. 10.4 Map of statistical tests

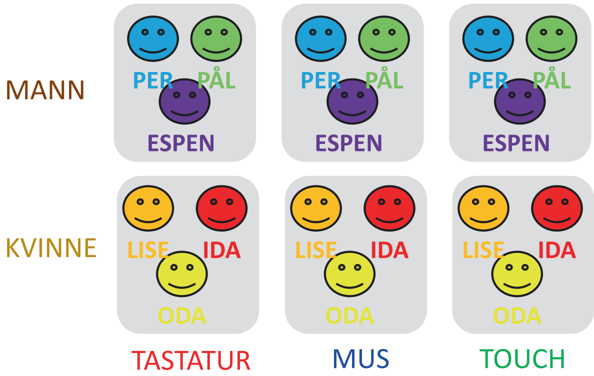

Fig. 10.5 Visualizing experimental design (in Norwegian)

Conclusions

This paper reviewed some of the literature on teaching inferential statistics together with our own experiences and observations from the classroom. We also provided examples of how we changed our inferential statistics teaching with the aim to make students perform inferential statistics more correctly. For a long time, the statistics teaching has been hindered by the limited availability of suitable statistics software. As known, the way the statistics is presented in software such as Excel leads students and researchers to perform statistics in a certain way and sometimes incorrectly. Although software packages (e.g., JASP) are making a huge leap in making inferential statistics available to students, there is still room for improvement in terms of the potential for software support for good statistical practices.

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Chapter 11
A Software Tool to Evaluate Performance in a Higher Education Institution

Arsénio Reis, Hugo Paredes, Jorge Borges, Carlos Rodrigues, and João Barroso

Introduction

Organizations, including businesses, government agencies, and nonprofit organizations, strive to meet their goals in the most effective and efficient manner possible. Higher education institutions (HEIs) are no exception, and the *introduction* of performance management is an important issue, which includes the introduction of evaluation processes regarding the human resources.

The HEIs, as organizations, are characterized by a specific context, with regular administrative staff and professors and researchers. The evaluation of the administrative staff is rather straightforward, with no particular assumptions—tasks are assigned and must be successfully executed. But for the professors and researchers, there are some challenges specific to their duties. It is harder to evaluate the quality of teaching or the value of the research work to the community in a broad sense.

The academic career is characterized by the diversity of activities that a professor can perform, including teaching, research, management, and community services. In addition, sometimes the activity of professors and researchers is developed in partnership with other institutions and other elements external to their HEI. They present their work in conferences or journals, give lectures and take part of academic committees in other institutions, participate in other institutions' projects, and develop their teaching and research work at their home institution.

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Because of the diversity of tasks, a professor can have, the information about these tasks is spread across different systems and databases. Some are internal databases of the institutions, and others are external sources, like ORCID or Scopus, that provide credible information about researchers and have been used as information sources (Chen, Ko, & Lee, 2013). Even if the information is kept in an institutional system, it is more probable it does not have all the necessary information for an accurate evaluation. Sometimes this information does change over the time, like the journal ranks in Scopus or Web of Science, leading to a need to obtain this information in real time.

The quantity of the typology of functions and forms of collaboration produces a large amount of data, scattered and difficult to obtain in a consolidated way. A comprehensive evaluation process is necessarily complex and very difficult to manage manually or semi-automatically.

With the introduction of the evaluation of teaching performance at the University of Trás-os-Montes and Alto Douro (UTAD) (UTAD, 2015a, 2015b), it became necessary to adopt a system to electronically support the process and comply with the professors' professional career regulation (Decreto Lei no 205/2009 de 31 de Agosto, 2009). Considering the described particularities of this type of evaluation, as well as the particular context of each higher education institution, it was decided to create an in-house specific system to evaluate the professors' performance. This approach has been successfully adopted on other information technology projects, related to teaching and learning (Borges, Justino, Gonçalves, Barroso, & Reis, 2017; Borges, Justino, Vaz, Barroso, & Reis, 2017).

In order to implement the evaluation process, regarding the performance of the professors, regulations were created. At UTAD, this lead to the creation of two regulations: the Teaching Evaluation Regulation (RAD) and the School Evaluation Regulation (RADE). The application of these regulations and their evaluation process were scheduled to be carried out in the academic year of 2016/2017, and four previous periods should be evaluated: 2004–2007, 2008–2009, 2010–2012, and 2013–2015. The process must be entirely supported by the IT solution, including data collection, evaluation by the evaluators, complaints of the evaluated persons, complaint analysis, and final evaluation's approval.

The system should be as autonomous as possible, collecting the data from other specific systems that record tangible aspects of the teaching activity, such as school services system, academic management system, scientific repository, DeGois portal, etc. (DeGois, 2017; Repositório Cientifico da UTAD, 2017).

The proposed solution fully supports the requirements of all the evaluation process tasks, in its various phases, providing a unique single tool, with an associated repository containing all the consolidated data. The data collection is automatically done by querying other systems, using manual data insertion only when the information does not exist in other systems. This feature is extremely important because it greatly simplifies and enables the evaluation process itself to be carried out.

Methodology

In order to implement a software solution able to support the evaluation process in its various phases, the approach was based on the paradigm of agile methodologies, on the assumption that it would be difficult to characterize the problem and to design a solution, in the context of uncertainty that existed at the beginning of the project (Cohen, Lindvall, & Costa, 2003). In spite of the evaluation process entirely regulated by the RAD and RADE, its form of implementation and, above all, access to the necessary data were not originally defined. It was adopted an incremental development methodology, starting from a simple solution and developing further versions, where new requirements and new forms of data access were integrated.

In terms of analysis, a multiphase process was adopted, as described below:

1. Analysis of the evaluation regulations, in which the workflow process, involving evaluators, was identified, as well as the data necessary to feed these processes.
2. Identification of data sources, necessary to collect the data previously identified in 1 and which would be absolutely necessary to develop the evaluation process.
3. Creation of a connection layer, for interoperability with other previously identified data provider systems.
4. Development of registration and flow mechanisms of the data, as regulated.

During the analysis, all the necessary information was identified, as well as the possible ways of obtaining it. Priority was given to the usage of online sources, with already developed operability interfaces. Some data may come from the Institutional Repository (IR) (Repositório Cientifico da UTAD, 2017), which is an online archive of this institution's research work and it is mandatory in many universities, according to the National Strategy for Open Science, promoted by the Ministry for Science, Technology and Higher Education. Some other data may arise from other online platforms, such as the ORCID or DeGois platforms, where each researcher information is updated by the researcher himself/herself (DeGois, 2017). The data sources were tested individually and were completed according to Table 11.1.

Table 11.1 Identifying the necessary data

Category	Subcategory	Source	Interoperability
Teaching activities	Courses	School services	Data import with database connection/manual input
Scientific production	Papers, conferences, books, impact factor	DeGois, institutional scientific repository, ORCID	Web services soap/manual input/import from excel files
Scientific production	Theses, dissertations	Institutional scientific repository/academic information system	REST JSON/manual input
Management activities	Positions held	School services	Manual input
Extension to the community	Cooperation with other entities	School services	Manual input

During the development, as shown in Fig. 11.1, several incremental iterations were performed, and at each iteration, functional prototypes were produced and tested by a diverse set of people, including professors from all five schools of UTAD (science and technology, human and social sciences, agrarian and veterinarian sciences, life and environment sciences, and health), administrative staff, IT staff, and software development specialists. Their opinion, in particular the one expressed by the professors, would then be used to start a new iteration and produce a new prototype. This iterative process took place over 2 months, in a total of four iterations, after which a satisfactory solution would be reached.

Following the above method, several modules have been developed separately, which correspond to the fulfilment of the different phases of the evaluation process. Thus, the following modules were developed in the same solution:

1. Collection, input, and submission of data.
2. Evaluation by the evaluators.
3. Complaint regarding the evaluation by the professor (if he intends to).
4. Analysis of complaints.
5. Final approval.

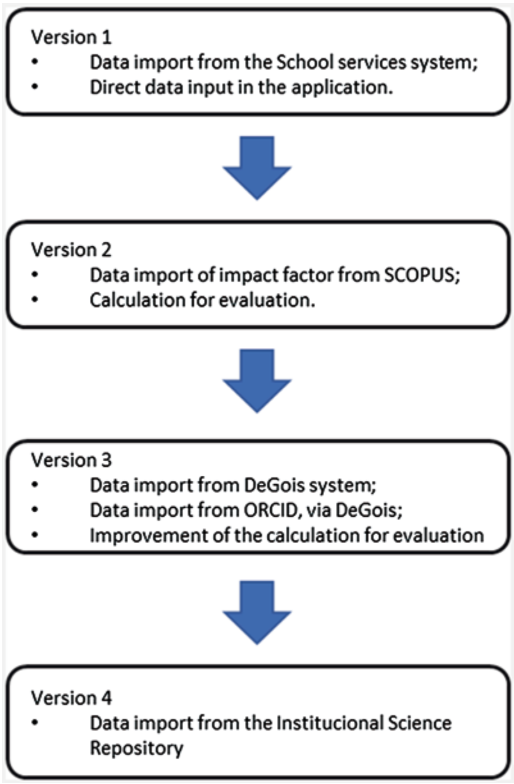


Fig. 11.1 Application versions of implementation

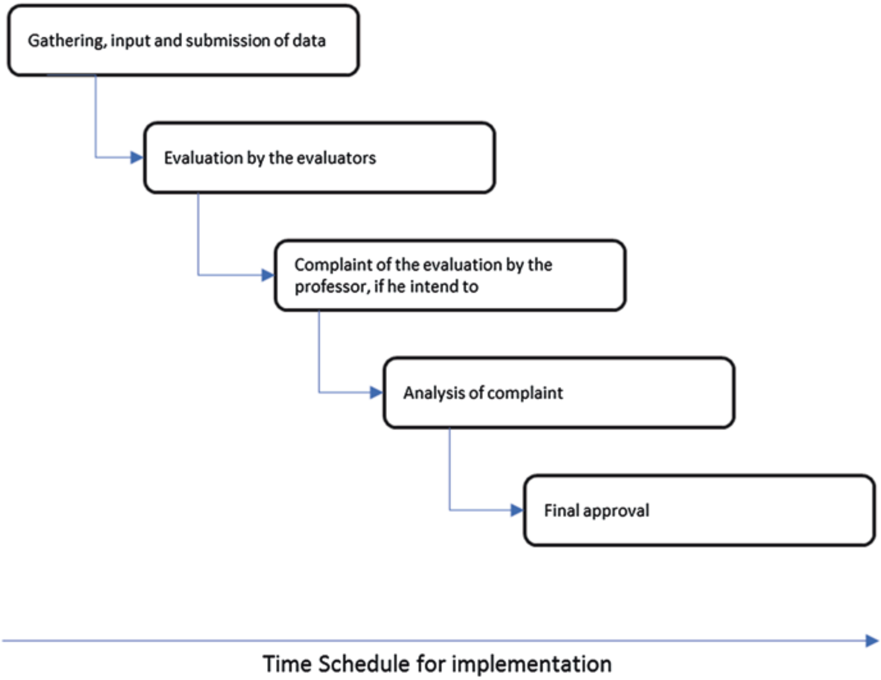


Fig. 11.2 Overlapping modules development

Because of the urgency to release the solution, it was decided to prioritize the development according to the timing of the evaluation process itself. Thus, the modules were successively developed, with some degree of overlap, as shown in Fig. 11.2. In this way, it was possible, during the available time, to develop the necessary functionalities to support the evaluation phases, as they were being implemented.

Description of the System

The system was developed as an online web platform and named "Plataforma de Avaliação de Desempenho do Docente" (PADDOC), which translates to "Professors' Performance Evaluation Platform."

Data Collection and Classification

In order for the system to work properly, it must have reliable data regarding the activities of the professors. So, the main challenge is to harvest the information for each professor and classify it according to categories and subcategories, as listed in Table 11.1.

To minimize the time and effort spent in managing the process, the data import was designed to be as automatic as possible. Still, some user interaction and decision were necessary in some phases, particularly when the correct subcategory cannot be automatically determined, or when the author cannot be correctly identified, or in case of missing data. The platform always tries to automatically identify the appropriate subcategory, but in many cases, the user must confirm the subcategory proposed by the system. The identification of subcategories depends on the category and sources being used.

Classifying the activities of teaching and management is quite simple, as all the necessary data is managed in the school services application. A direct import using a database connection, with an automated algorithm for classifying the data, was suitable. On the other hand, the classification of thesis and dissertation required some additional software development. The university uses DSpace version 3.2 for its Scientific Repository, which doesn't provide an API neither implements a list of authors for the advisor and author of each thesis and dissertation. On the one hand, the lack of an API was overcome by writing new code to query the database for the records of an author or advisor and with some PHP code to present the data in an HTTP REST API, returning it in JSON format. On the other hand, the lack of an authorities list for the authors was much more difficult to overcome. In fact, author identification is the biggest difficulty, because author names are usually shortened in papers and other articles, making the automatic identification difficult or even impossible.

Papers, conferences, books, and book chapters were imported from the DeGois platform, which is an online platform to register the curriculum vitae (CV) of Portuguese researchers. Each researcher has a unique number that identifies his/her CV, which must be entered in PADDOC by the researcher and then used to communicate through an API interface with the DeGois platform. The usage of the ORCID platform was also considered for this process, but as the DeGois platform already allowed data import from the ORCID system, researchers were educated to first import the data from ORCID to DeGois and then to PADDOC. As for ranking the items of each category, the best quartile between Scopus and Web of Science was used. The quartile values for each item (journal, conference, etc.) were downloaded as an Excel file from the Scopus and Web of Science web sites (https://jcr.incites.thomsonreuters.com for ISI and http://www.scimagojr.com/journalrank.php for SCOPUS) and then uploaded to the PADDOC platform. The relation between papers and other items, and the quartile value, was created using the ISBN or ISSN, which is a mandatory field for the paper's records, and the year of publication.

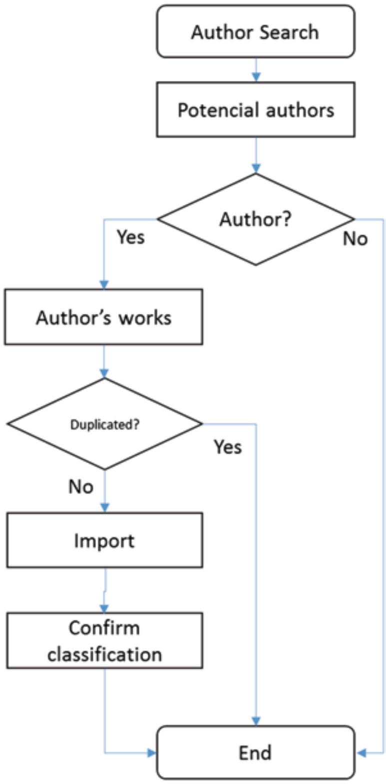
The data that was not electronically imported, due to the lack of support information systems or because it was missing on the existing information systems, had to be manually entered and properly certified with documentation, which was, in most cases, digitalized and uploaded. Another concern is the duplication of data. Because data can be retrieved from different sources, all new inputs must be compared with previous information to prevent duplications.

To address all the previously referred concerns and, in particular, the authors' identification, we developed an algorithm to identify probable author names, based on the full name of the researcher. The algorithm is simple. Firstly, it searches for the author's last name, which is commonly the one used in articles, and then excludes the author's names that have any word or initial that isn't equal to any of the words or initials of the full name in analysis. So, when a professor searches for his work in several platforms, his full name is used to obtain probable names. These names are listed to the professor, associated with the work, and the professor validates each of the listed names and items. The algorithm also detects duplicated items, preventing their automatic import. This import and validation process is executed in a temporary spool, and the data is imported to the final database only after a final validation. In Fig. 11.3, a flowchart describes this process.

Certifying the Data

As the quantity of information expected to be stored in the system would be significant, and thus the evaluators could not verify one by one all the items saved in the system, automatic validation or certification of the data was necessary to ensure that no false information would be loaded. The following rules were adopted:

Fig. 11.3 Used algorithm



1. Data imported from an internal official institutional information system is considered trustworthy and doesn't have to go through further checking. It cannot be edited by the evaluated professor—He can only accept or reject it.
2. Data imported from a third-party system, such as DeGois, alongside with a document object identifier (DOI) or link would be accepted as validated or certified, if it points to a trusted domain, e.G., a journal site indexed by SCOPUS or web of science, or an official institutional information system.
3. Data entered manually, with a link or DOI to certify its validity, would be accepted only if it points to a trusted domain, as a journal site indexed by SCOPUS or web of science, or an official institutional information system.
4. Data entered manually with no DOI or link must be certified by an official document, in PDF format, issued by the rightful information owner. For example, if a professor claims to have held a management position in "INSTITUTION a" and our university has no record of it, then "INSTITUTION a" must issue a certified document stating so.
5. Data saved that do not comply with the previous items is rejected.

The Calculation

The PADDOC system uses four categories: teaching (T), research (R), extension (E), and management (M). Table 11.1 shows the main subcategories that can be considered in each category. There are other subcategories that won't be presented is this paper. Each category can have a different weight factor (Wf) for the calculation of the final evaluation, and each item of a subcategory inside a category has a defined value (Iv), which is specific to each subcategory. The Wf and the Iv are defined in the regulation documentation RAD and RADE. In the case of articles published in journals ranked by Scopus or Web of Science, the Iv takes into account the best quartile between Scopus and Web of Science.

The final evaluation is calculated as follows: (Wf of T) × (Sum(Iv) of subcategories of T) + (Wf of R) × (Sum(Iv) of subcategories of R) + (Wf of E) × (Sum(Iv) of subcategories of E) + (Wf of M) × (Sum(Iv) of subcategories of M). The final grade has no limited value.

Use Cases

The use cases that PADDOC realizes correspond to the execution of the various stages of the evaluation process, plus the cases of data management (import and validation) and information reporting. Figure 11.4 displays the diagram of the use cases realized by PADDOC.

Architecture

A web model-view-controller (MVC) application—the PADDOC system—was developed to support the process previously described. For data storage, it is used a SQL database to store structured data and a digital repository to store documents, uploaded by the users and later manually certified, as well as other data with no DOI or link references. The repository is based on Microsoft SharePoint technology. The data import was conducted using two methods: (1) using Excel files and (2) using web services from third-party providers.

The PADDOC system was implemented according to the diagram in Fig. 11.5, using. NET technology with MVC (Leff & Rayfield, 2001; Microsoft Corporation, 2017) and the Visual Studio development environment (Microsoft Corporation, 2015). These technologies were chosen mainly due to the team experience in previous projects, on which the system's architecture was similar (Paulino, Reis, Barroso, & Paredes, 2017; Sousa et al., 2009). The support for universal access was observed, in order to comply with the institutional guides to provide access for all users to all information systems (Gonçalves, Rocha, Reis, & Barroso, 2017; Paulino et al., 2016; Reis et al., 2017; Reis, Barroso, & Gonçalves, 2013).

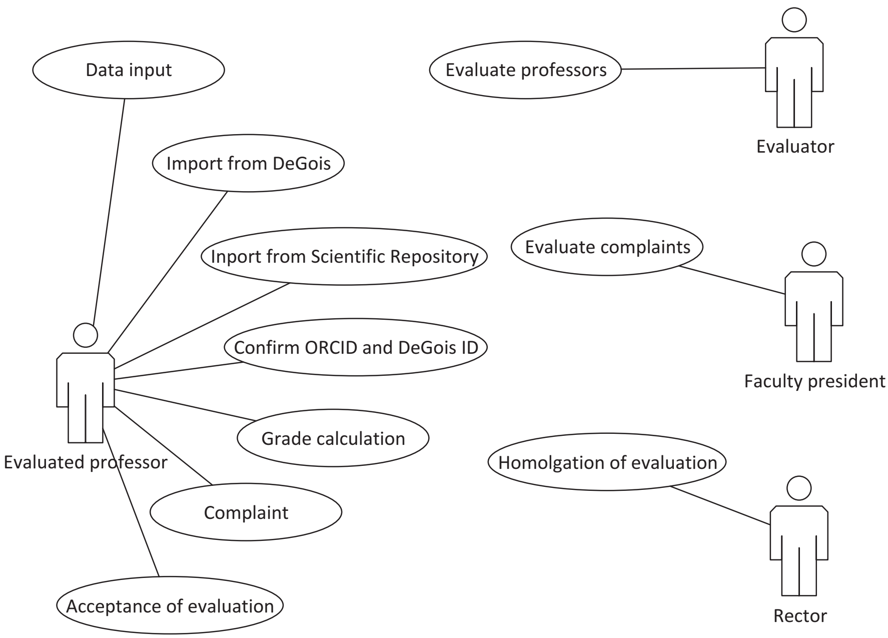


Fig. 11.4 Use cases

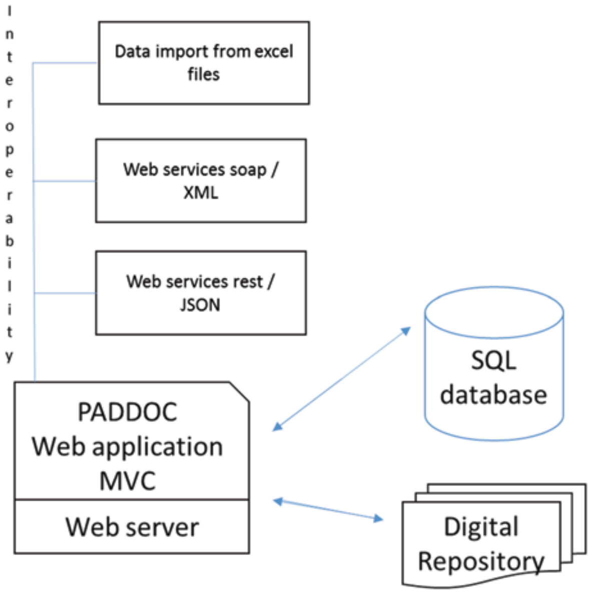


Fig. 11.5 System architecture

Results

The PADDOC system was well accepted by the users, and we confirmed that the evaluation process did not introduce unnecessary actions by the professors. The system gathers the maximum possible data from several sources and only requires the user intervention when needed.

Table 11.2 shows the information collected during the process.

During the evaluation period, 24,884 PDF documents were uploaded, although for many items, a PDF document wasn't necessary because the source of the data was considered certified, e.g., ORCID and DeGois. If the evaluation process was conducted without the support of an electronic platform and all the documents had to be printed, then each evaluator would have to check and certify thousands of printed documents.

Conclusions

The process of evaluating the professors in the Portuguese universities is still at its beginning, and it is natural that it will undergo several adjustments. So, although PADDOC was developed to a full-featured system, it will also have to be adjusted to comply with the process.

Table 11.2 Collected data

Periods of evaluation	No of evaluated professors	Records created in the SQL database	Uploaded documents to the repository
2004–2007	38	3518	2476
2008–2009	74	4620	3445
2010–2012	97	9806	7495
2013–2015	128	15,010	11,468
Total	337	32,954	24,884

The system began to be designed and developed in September 2015, and the evaluation process started in October 2016. During the period between the two dates, the evaluation regulations were revised, and the development process was adjusted to each newly revised regulation. The evaluation process already begun with the full support of PADDOC. Considering the novelty of the process, as well as the positive reaction of both the evaluated and evaluators, it can be concluded that the PADDOC project fulfils the ultimate objective of electronically supporting the process of evaluation of professors at UTAD.

During the period, from October 2016 to the beginning of 2017, 24,884 items were received in the form of PDF files, certifying various aspects of the activity of professors, e.g., participation in conferences, juries, publication of articles, management positions, participation in projects, etc. The response of the system while processing the data and follow-up of these items is excellent, and no degradation of performance has been recorded at any level (application, infrastructure, hardware, etc.).

Future Work

In future evaluation cycles, professors and researchers should be able to follow the evolution of their own evaluation parameters, since the beginning of the evaluation period. PADDOC will be adjusted accordingly, providing professors with a valuable tool to know the evolution of their performance during the current evaluation period. In this way they can adjust and focus on their professional activity according to the objectives that they intend to achieve.

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Chapter 12
The Educational Impacts of Minecraft on Elementary School Students

Thierry Karsenti and Julien Bugmann

Introduction

Minecraft is the second highest-selling videogame of all time. It is also used educationally in American, Swedish, and Canadian schools. Since an increasing number of schools have begun to use this game in their classrooms, it has become important to scientifically investigate its educational potential to better understand its impact on students. In the case of this research project, the use of Minecraft in a scholastic setting was investigated while focusing on the following objectives: (a) highlighting the main uses of Minecraft in a scholastic setting and (b) identifying the main advantages associated with the scholastic use of Minecraft.

Minecraft could be considered an online, modern-day version of the classic Lego building block toys. Lego blocks are connected and assembled to create a practically unlimited variety of structures. The same is true for Minecraft, except that instead of handling building blocks, users operate in a virtual world using pixelated cubes. The main limitation for both Lego and Minecraft is the user's imagination. Minecraft gives users the additional advantage of being able to play safely with water, earth, fire, trees, and other natural elements. Expanding on this compelling concept, an educational version of the videogame was released late in 2016.

While designing this educational version, Microsoft and Mojang AB sought the input of experienced teachers to help students acquire and develop key learning aptitudes. Creativity, student engagement, and collaboration between users are just some of the skills that can be developed through gameplay. These benefits provide the educational utility of the game and help explain its surging popularity. This trend raises a few questions. What are the main findings on the educational uses of Minecraft? Can students learn effectively by playing it? Does it provide positive stimulation? Are there any drawbacks to using this type of videogame at school?

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These questions have theoretical and practical implications, and they all stem from a single key question: Why focus on the use of videogames at school?

The simple answer is that the usefulness of educational games has long been validated by numerous studies (Dewey & Deledalle, 1983; Piaget, 1959; Winnicott, 1975). Logically, therefore, digital games should be examined as well. This becomes even more apparent when one realizes that videogames are the world's leading cultural industry. However, it has not always been easy to use games, especially videogames, in class, even though empirical studies have demonstrated that they can provide environments that encourage certain types of learning (Baranowski et al., 2003) and they can have positive "cognitive, affective, and psychomotor" effects on players (Shaftel, Pass, & Schnabel, 2005). When a highly engaged player enters the flow state (Csikszentmihalyi, 1990), these circumstances are extremely favorable for learning. The player's high engagement allows for a full immersion into the online environment. The player is then more open to learning through the interactions, discoveries, and experiences provided by the game. High engagement also limits distractions, loss of motivation, and misunderstanding of content, all negative factors for learning. Thus, gamers are free to discover and to cognitively focus on the task at hand. In addition, videogames help students acquire the twenty-first-century skills (Ontario Public Service, 2016) that they will need in their future careers and lives. The development of these competencies becomes increasingly vital when one considers that almost 15% of Québec students (reports from 2013–2014) drop out of school without a diploma or qualifications (Ministère de l'Éducation et de l'Enseignement, 2017).

One of the major benefits of using videogames for learning is the great enjoyment they entail, a critical condition for learning. At school, Minecraft can not only help students develop problem-solving and teamwork skills, but it can also increase their motivation as well. These are the main findings of Méndez, Arrieta, Dios, Encinas, and Queiruga-Dios (2016), who analyzed videogame use by architecture students.

Furthermore, according to Callaghan (2016), the educational use of Minecraft fosters conditions that are beneficial for learning, particularly for engagement, collaboration, and creativity. In addition, Minecraft boosts motivation through the use of creativity to improve problem-solving skills (Thorsteinsson & Niculescu, 2016). Some authors feel that Minecraft would also be beneficial for teachers, because it allows for the design of creative student projects. Others claim that Minecraft has an "immense" impact on education because it encourages learning through play, creation, and cooperation in class (Nebel, Schneider, & Rey, 2016). For all these reasons, growing numbers of schools have been using Minecraft to complement traditional teaching practices and teach history, as described by Craft (2016). This sandbox strategy game allows users to learn while using the informal setting it affords (Bebbington & Vellino, 2015). MinecraftEdu, the first educational version of Minecraft, has been shown to stimulate students' interest in science and the use of information and communication technologies (ICT) in class (Pusey & Pusey, 2016).

As 21st-century skills (Ontario Public Service, 2016) continue to increase in importance for current and future generations, it appears Minecraft may be able to put a portion of these skills into practice, as well as increase user digital literacy after only 6 months of use (Morgan, 2015). Minecraft's potential has also been tapped for real-world applications such as architectural projects, as demonstrated by Magnussen and Elming (2015), who described the Minecraft-based remodeling of Copenhagen neighborhoods by students in collaboration with city authorities. The creativity that this game elicits from users (Moffat, Crombie, & Shabalina, 2017) allows students to learn about technology, teamwork, and construction (Overby & Jones, 2015). It also presents a unique opportunity for players to be creative in virtual environments that would otherwise be difficult to recreate in the real world (Cipollone, Schifter, & Moffat, 2015). To further illustrate Minecraft's educational potential, positive outcomes have been observed in varied educational contexts. For instance, studies have shown significant positive impacts on students with autism spectrum disorders (ASD), with improved collaboration and social connectivity (Riordan & Scarf, 2016). Because the game has no specific objectives, ASD students can immerse themselves in their own personal narrative, allowing them to create and explore (Riordan & Scarf, 2016). Moreover, there is an online network dedicated to Minecraft play by ASD users (http://www.autcraft.com), which opens the door to new social interactions (Ringland, Wolf, Faucett, Dombrowski, & Hayes, 2016).

Methodology

The main results of this study are presented in the context of the project's two research objectives:

- To highlight the main uses of the Minecraft videogame in schools.
- To identify the main advantages associated with the use of Minecraft in schools.

To properly illustrate the experimental context of this study, a brief description of the supervised gameplay sessions will be presented in conjunction with screenshots and photos of student artifacts. Finally, the main uses and benefits to the scholastic use of Minecraft will be presented.

An exploratory research design (Trudel, Simard, & Vonarx, 2006) was used for this research project as this approach can be used as the foundation on which future research is built and because an exploratory research project affords the opportunity to define educational contexts that currently receive little attention.

Participants

A total of 118 elementary school students (63 girls, 53.4%; 55 boys, 46.4%) participated in this study. All students were aged from 9 to 12 years, with a mean age of 11.3 years. All participants were enrolled in French-speaking elementary schools in the Greater Montreal Area in the province of Québec, Canada. The schools were located in areas where the poverty index fluctuated between seven and ten (where ten indicates the lowest socioeconomic standing). Students were recruited on a volunteer basis, with the consent of their parents and the schools. Data were collected during the 2016–2017 school year.

Data Collection Tools

A total of ten data collection tools were used throughout the study (Table 12.1). The breadth of instruments used can be explained by examining the writings of Trudel et al. (2006). These authors indicate that exploratory studies can also be used to determine the best approaches to data collection used to describe aspects of the reality under investigation.

Table 12.1 Ten data collection tools used throughout the study

Research surveys ($n = 4$) completed by all students ($n = 118$)
Semi-directed interviews outside of game time ($n = 6 \times 30$ min)
Short individual interviews ($n = 118 \times 5$ min) during game time
Group discussions with students during the Minecraft gaming sessions ($n = 3$)
Observations and analysis of supervised gameplay videos ($n = 6 \times 75$ min)
Observations and analysis of think aloud protocol videos ($n = 3 \times 30$ min) collected during supervised gameplay
Individual interviews with teachers and moderators during supervised gameplay sessions ($n = 6$)
Tracking of students' advancement through the game levels
A weekly diary by the Minecraft moderator ($n = 14$)
"Digital footprints" (Jaillet & Larose, 2009) or student-generated Minecraft products

Data Analysis Strategies

Surveys were used to collect both quantitative and qualitative data derived from Likert responses and open-ended questions, respectively. Accordingly, a mixed-method data analysis approach was used. Quantitative data analysis was conducted using SPSS 23 and the online survey application Survey Monkey2 to produce and analyze descriptive statistics. These preliminary data were then validated and expanded with a qualitative analysis of the responses to the open-ended survey questions using QDA Miner 3. This consisted of a content analysis (L'Écuyer, 1990; Miles & Huberman, 2003) with semi-open coding of students' responses concerning the main study objectives (uses and benefits). The interview data were also analyzed based on the protocols developed by L'Écuyer (1990) and by Miles and Huberman (2003). A content analysis approach was adopted using QDA Miner, an approach ubiquitous in qualitative data analysis (Karsenti, Komis, Depover, & Collin, 2011).

Methodological Strengths and Shortcomings

One of the main strengths of this study is the unique methodological approach it employs. The combination of data collected from surveys, interviews (during or outside of gaming sessions), think aloud protocols, journals, tracking of student progress, and "digital footprints" allows for substantial data triangulation and validation. This variety of methods provides an opportunity for deeper analysis and interpretation of results. However, certain shortcomings must be considered. First, the use of student perceptions is a limitation that was offset, at least partially, by the high number of participants ($n = 118$) and the variety of data collection methods, including observations and analysis of video recordings. To reduce this methodological bias, responses by different types of participants were systematically compared, and differences were highlighted when appropriate.

The second shortcoming concerns the nonrandom selection of participants. The study sample does not necessarily represent the target population (elementary school students in the Greater Montreal Area). It would have been practically impossible to generate a random, representative sample, mainly due to logistical constraints. Therefore, convenience sampling was used to recruit non-probabilistic volunteer participants. The only requirement for participating in the study was to attend supervised Minecraft gaming sessions.

A Scholastic Program Adapted for Minecraft

To guide the students' use of Minecraft, an educational Minecraft program called *Become the Minecraft Master* was created specifically for this research project (Fig. 12.1). Briefly, this program includes 30 educational tasks that call upon various skills and competencies. They are grouped into ten levels that progress from the simplest to the most complex. This presentation allows students to progressively discover Minecraft and advance toward full mastery by the end of the program. For example, students began by personalizing their user interface. In the second level, they explored the game. Eventually, they learned to master the digital environment along with the gaming tasks. This progressive structure was designed to help students understand and control the digital environment.

To encourage students to advance through the program, color-coded levels were introduced during gameplay. For example, after completing level 1, students could move up to a level called Minecraft Master Level 1 Yellow and eventually advance up to the 10th level, Minecraft Master Level 10 Platinum. In addition, because each level contains three different tasks, the moderator (a Minecraft expert) validated each completed task with a Minecraft Graduation Certificate. Students had to collect 30 graduation certificates to become a certified Minecraft Master.

To help promote student engagement, students were awarded Minecraft Master wristbands once they successfully completed a level. It is important to note that, as with the certificates, the moderator distributed the wristbands. Upon validation, students received a wristband featuring the name and color of the level as well as some game visuals. The wristbands provided tangible extrinsic motivation for the students to engage in gameplay and to achieve as many levels as possible.

The moderator's essential role in this study cannot be understated, as he was the main link between the research group and the students. The journal of his interactions with students provided useful contextual corroboration for the observations conducted throughout the study. In the sessions, students were offered a choice of gameplay styles. They could participate in the "creative" mode, with access to all the objects. Alternatively, they could opt for the "survival" mode, where they had to design and build their own objects to progress in the game and to survive and thrive in a given environment. As the gaming session progressed, students who achieved the Minecraft Master level could access additional, more difficult levels. These Minecraft Pro levels required that students complete significantly more complex tasks (Fig. 12.2). Students also received certificates for these upper levels after 6 or 8 weeks of participation.

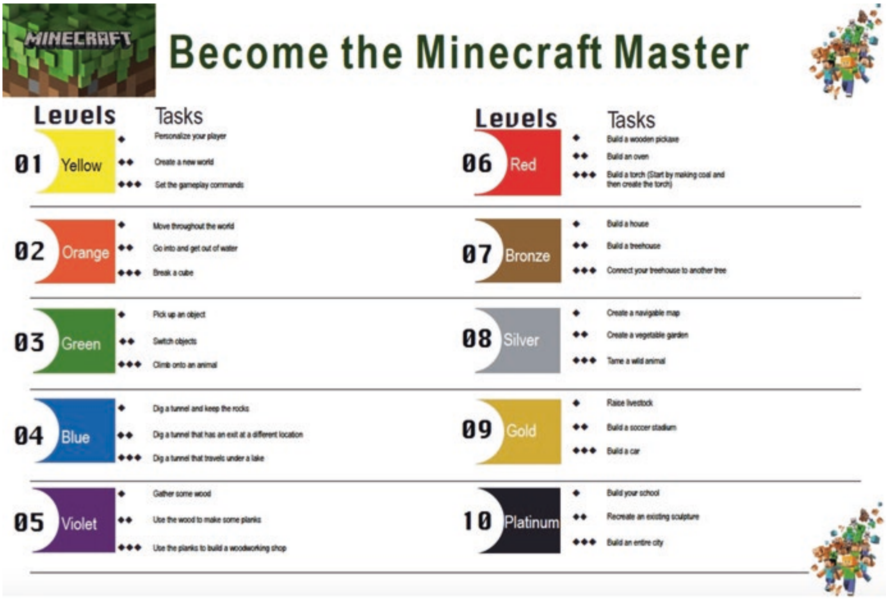


Fig. 12.1 Minecraft Master levels

Fig. 12.2 Minecraft Pro levels

Results

The results highlighted in this section first showcase examples of student work achieved with the Minecraft videogame. Second, we detail the main academic impacts of using Minecraft in schools.

Examples of Student Work

Several screenshots were taken during the gameplay sessions. Based on Jaillet and Larose's (2009) concept of digital footprints, it appears important to present these as results to demonstrate the students' proficiency, creativity, engagement, and motivation as well as the complexity of the structures they designed and built. For example, they built impressive houses (Fig. 12.3), a soccer stadium (Fig. 12.4), a spaceship (Fig. 12.5), and the Titanic itself (Fig. 12.6).

Fig. 12.3 A house on water created by elementary students

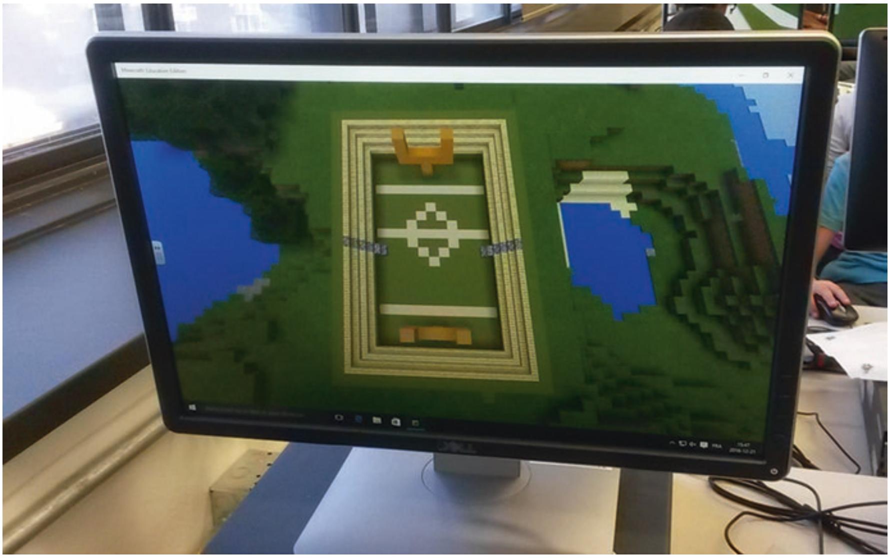
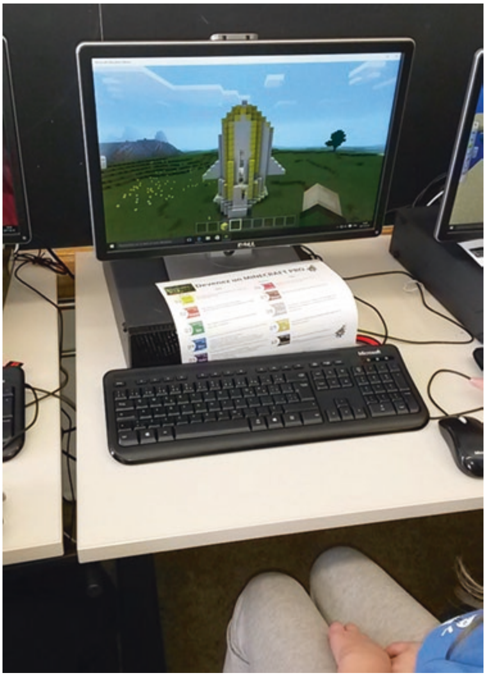


Fig. 12.4 A soccer stadium created by elementary students

Fig. 12.5 A student building a spaceship



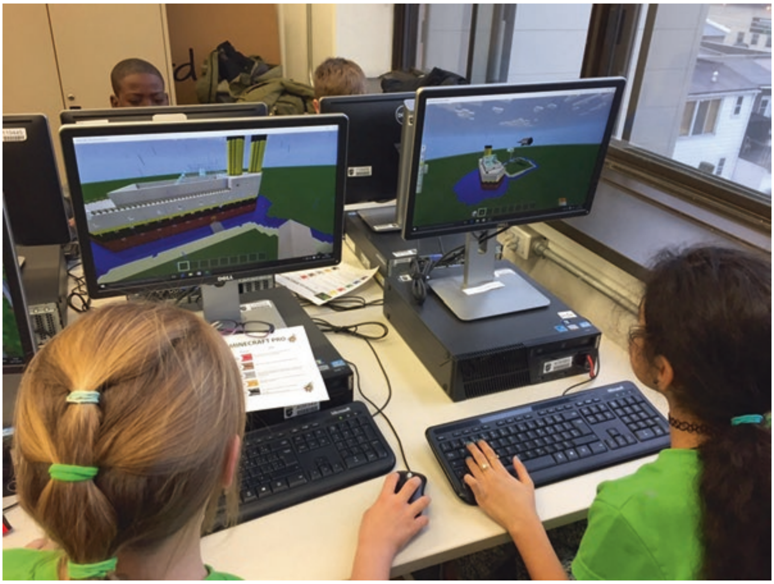


Fig. 12.6 Two students building the Titanic

What Are the Educational Impacts of Using Minecraft?

The study results highlight the many educational benefits of using Minecraft in class. These are listed and are discussed below.

Motivational Benefits for Students

The results generated from the variety of data collection methods used in this study indicate that playing Minecraft at school has a significant impact on student motivation. Among several outcomes that demonstrate this point, the most striking may be an email that one student's father sent to a school principal. The father says that even though school had been out for quite some time, his daughter wanted to go back so she could play Minecraft. In addition, although participation in the Minecraft project was voluntary and the sessions were held after school, the moderator reported very few absences in his detailed record of attendance. In his opinion, the students were "very motivated"[1] and showed "lots of interest in the Minecraft activity." He also pointed out that "[i]t's an optional activity, and they come to school because they want to." One school principal even had to turn some students away due to high demand for places in the program.

[1] Quotes were translated by the authors from the original French.

The survey responses indicate that 77.1% of students found playing Minecraft at school "extremely" fun. This trend was supported by the student interviews:

- "It isn't real. It's cool. We can build things."
- "I like building cities."
- "I like being able to construct things."
- "Minecraft, compared to the other cubic games, is really the most interesting game."
- "I like creating, making houses, pools, and all that."
- "I like playing Minecraft a lot."
- Minecraft is "fun, and at the same time, it's educational."
- "We have fun when we play, but when we have fun, we learn things."

A Highly Beneficial, Level–Based Structure

Overall, students followed the proposed structural levels throughout the duration of the activity. They also progressed quickly: some advanced to more difficult levels after only a few sessions (almost 19% of students). The moderator confirmed this trend at the fourth session: "Almost all the students are advancing through the levels, and at least half the class has passed level 7, while many have finished level 9." Game mastery came rapidly for most students: after only a single session, even novice students could move, select tools, throw them, and so on. According to the moderator, even in the first session, "Everyone has now understood how Minecraft works. All the students know how to move, break down, retrieve, and select blocks." It is noteworthy that the levels were not all easy and that student success depended on perseverance and teamwork: "The levels were pretty hard for me, since I had never tried" (student). The built-in level structure also required students to read and follow directions, giving them practice in some key methodological skills for academic success.

Many Academic Impacts

The results also provide insights into how Minecraft scaffolded student independence and autonomy, as indicated by the students themselves: "You can build at your own pace. You decide what you build, and that's what I like." Student collaboration and mutual support were also apparent during the sessions: all students reported helping at least someone, and 90% said that they had played in teams. The moderator also stressed the importance of collaboration, suggesting that the "good cooperation between the youngsters" allowed for "faster advancement through the levels," "probably because they have other, more expert students to help them." This demonstrates effective cooperation between students, which allowed for the creation of a positive learning environment and the development of social skills. The interview results also revealed that Minecraft nurtures qualities such as collaboration, teamwork, and helping others. When students were asked what they did when a problem occurred during gameplay, many of their responses underscored the importance of teamwork:

- “I ask friends who are better at playing than I am.”
- “I’m learning how to be part of a team.”
- “Teamwork is more fun.”
- “[others] help me a lot, so I can learn more things.”
- “In Minecraft, we’re more together, we’re tighter, and we work much better in teams than on other projects.”
- “When I have a problem, I usually try to find the solution by asking my friends what they think about it.”
- “Working in a team is easy. Being alone, it won’t be easy.”
- “I ask my friend for help.”
- “I ask a friend [who is sitting] next to me, and then he helps me.”

Based on students’ statements, the potential for having fun during gameplay was determinant for the positive interactions observed between the children: “It’s like a playground, only it’s virtual.” The results also revealed that the structured Minecraft system greatly increased students’ feelings of self-efficacy and self-esteem: “It feels like I’m a pro, and they ask me questions that I know [the answers to]” (student). Students also improved their oral communication skills: “We learn how to communicate with each other better” (student). Furthermore, Minecraft encouraged creativity. The students designed several online environments and proposed new types of building structures, both showing impressive quality and ingenuity: “The students are quite creative” (moderator). This creativity appeared to stem, at least partially, from their competitive nature: “We see more and more creativity due to the competition between these groups” (moderator). The students particularly enjoyed having to reconstruct a model of their own school (a required task), as demonstrated by the survey results. They also appreciated the inherently creative nature of Minecraft, according to the interviews:

- “Imagination has no limits.”
- “I like building things. I’m really good at it. I have a lot of imagination in that.”
- “I’m learning to make objects, to build objects.” “you can do what you want.”
- “We can put whatever we imagine.”
- “We can build what we want. We can invent what we want, create things, like inventing something that doesn’t really exist.”
- “We can create things.”
- “We can build lots of stuff.”
- “There’s really no limit to what we can do.”

Students were also able to develop information search skills, particularly when they had to find out how to advance through the levels. They also improved their problem-solving skills: "Going through the levels taught them to read and understand written instructions" (moderator). In the interviews, students said that playing Minecraft at school made them "really think" to solve problems. For example, at one point, to advance to another level, students had to find a way to gather some coal: "To get coal, you need to solve a problem" (student). The analysis of results also indicated that the game required students to follow logical sequences involving the use of inductive and deductive mathematical reasoning. The moderator corroborated this finding: "I also insist on having them understand the logical sequence of the levels. Like, for example, we make them build a shop before an oven because you need to have a shop before you can build an oven." One of the more popular tasks required students to learn basic agricultural and farming notions such as crop tending and livestock rearing: "Like plants, what we need to make them grow" (student).

In the students' opinion, the scaffolded gameplay environment required them not only to use the Internet as a search tool but also to apply themselves in their quest for answers: "To do things, you can't go fast. You need to think and concentrate to do things in Minecraft." In addition, according to the moderator, students who were initially unable to complete a task developed independent research skills in order to gather "information from online encyclopaedias, YouTube, or websites like Minecraft Wiki," a Wikipedia dedicated to Minecraft. Furthermore, as supported by the observations and analysis of the videotaped sessions, both students and the moderator used YouTube to troubleshoot gameplay issues. In addition, the responses in the student interviews corroborated the moderator's initial observations and the videotapes:

- "I go online, I write 'how to build a fort in Minecraft', I click on 'enter,' and it shows me. Then I go back to Minecraft and I do it."
- "I go on YouTube to see how to build it."
- "Last time, I went on YouTube and I built a house."

Examination of videotaped data also showed that many students used YouTube to figure out and understand basic gameplay strategies and commands. In addition, the group observations and individual interviews indicated that Minecraft required the students to focus on their writing, for instance, when they had to create signs. Good writing skills were also required when the students had to name their finished buildings and neighborhoods. Additionally, the students often communicated with classmates in writing, as evidenced by the interviews: "We practice our writing, our French grammar." Interestingly, the students, who were generally French-speaking, improved their English as well: many of the online resources were available in English only. Again, the student interviews support this finding: "Knowing English was important […] to know what the name of the block meant." The results also indicate that Minecraft required the players to persevere in difficult situations: "Perseverance […] their progression is constant" (moderator). This result was confirmed by the videotapes, which showed students starting certain levels over repeatedly.

The survey results showed that as the students played Minecraft, they learned about mathematics (e.g., surface area, perimeter), computer science, and geography. These results are supported by the interviews:

- "It teaches me to count well, because to build you need to count well, because in Minecraft you need to have even-numbered buildings. There are also odd-numbered buildings, but those are harder."
- "I'm learning mathematics, also geography, volume, and the measurements to know how many blocks to put."
- "Mathematics, if, for example, we say: Make a third of the house this colour."
- "I have to calculate the exact number of blocks I need."

Students, both girls and boys, developed ITC skills, computer programming, and computational logic skills during gameplay. This was largely thanks to the lines of code that can be applied throughout the game. In fact, almost 80% of students said that they used code to advance to a higher level. This trend is reinforced by excerpts from the student interviews in which they reported using programming to "teleport, how to switch day and night, how to add or take away the bad guys." This aspect is of interest because it demonstrates that Minecraft can be used to teach students how to code. The significance of this finding cannot be understated, especially in light of the importance of coding and computer programming for today's students (Karsenti & Bugmann, 2017). Another benefit of using Minecraft at school is that students can use it to learn about history, especially at the Minecraft Pro level, where they create environments based on historic events and geographic sites (e.g., the construction of the Eiffel Tower, the sinking of the Titanic, events held at the Roman Coliseum).

Finally, the moderator proposed that Minecraft could be used at school to produce a range of learning outcomes—"What goes up must come down, so it demonstrates gravity. They don't even notice that they're learning these kinds of things, but later on in life they'll say to themselves: 'Oh yes, that was obvious.'"

Conclusion

At a time when the use of Minecraft in schools is becoming increasingly popular, this study, conducted with 118 elementary school students, aimed to better understand its educational benefits. The collected results indicate that there is significant pedagogical interest in the scholastic use of Minecraft. Through data analysis, numerous benefits, other than student motivation alone, were identified in the context of supported and planned use of the videogame. However, despite the multiple observed benefits of using Minecraft in school, it seems important to reiterate that this study in no way indicates that unsupervised use of videogames is beneficial. On the contrary, the benefits measured throughout the study were observed in the context of an intentional, planned, and supported use of Minecraft in schools. Therefore, it would be inaccurate to describe this study as focusing on the in-class management of videogames as learning tools, the lack of which can lead to inappropriate uses of this resource. Thus, in spite of the positive outcomes demonstrated in this project, it is necessary to provide students with a framework that limits obsessive use of the videogame. A videogame such as Minecraft, which offers significant pedagogical benefits, will not be effective in the absence of such a structure. Without these boundaries, students may not want to stop playing and may avoid many potential learning opportunities. It is for these reasons that the internal (difficulty levels) and external (presence of a moderator) structures were built into this exploratory study.

Finally, it goes without saying that a critical balance should be struck between the use of videogames and other activities. There is a big difference between obsessive gaming and using games as exceptional teaching and learning tools, with yet undefined potential. Both parents and educators are responsible for overseeing the use of videogames like Minecraft to ensure that they provide appropriate support for learning and the development of technology skills. This will allow students to benefit from the full educational potential of this incredible game and others like it.

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Chapter 13
Demonstrating Online Game Design and Exploitation for Interdisciplinary Teaching in Primary School Through the WeAreEurope Game for EU Citizenship Education

Tharrenos Bratitsis

Introduction

The exploitation of digital games in education is gaining momentum over the past few years. Research highlights the benefits of this trend on the cognitive and social level of children (Dede, 2009; Kiili, 2005), while the supporters of digital game educational utilization are constantly increasing (Gee, 2003; Trybus, 2009). Van Eck (2006) suggested that for a game to be successfully integrated in the teaching practice, teaching goals need to be set and examined in order to create evaluation criteria. Prensky (2002) commented upon the design of educational games, stating that they need to be fun as well. But overall, the exploitation of digital games for educational purposes holds a significant position in the academic debate.

The notion of citizenship is becoming more widely dealt with, especially within the EU. It is connected to the membership within an organized community, and throughout the literature, the available definitions mainly describe the elements/qualities of a good citizen. This approach has been valid from Ancient Greece until today, with the incorporation of various peculiarities on these attributes, based on the social status on each time period.

Based on these two pillars, the idea of WeAreEurope emerged. It is an EU-funded project with the aim to create an online digital game for educating primary school children (ages 6–10 years old) about citizenship in the European context. In order to design and implement this game, several steps were taken which are described in this chapter as means of demonstrating the process of deploying digital games, online, in particular, for educational purposes. These include building the theoretical grounds for game design and the disciplinary area (citizenship education),

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structuring the learning content, implementing the final product, and conducting pilot testing sessions.

The chapter is structured as follows: initially the theoretical framework for both game design and citizenship education is briefly presented. Then, the design and implementation of the online game are described, correlating the game features with the proposed framework. The pilot assessment process is then described, and preliminary results are presented. Finally, the remaining tasks for completing the game deployment are mentioned, thus fully exemplifying the game creation process.

Theoretical Background

In this section, the two elements of the theoretical background of this chapter are presented. The first regards the design of educational digital games and the second the disciplinary area, in order to identify design principles and teaching content.

Digital Game Design: The LiX Framework

This section argues upon the theoretical background needed to support games utilization in the classroom for learning purposes. In particular, it focuses on enhancing students' motivation and increased learning outcomes based upon the constructivist and situated learning frameworks.

According to Christophel (1990), the teaching process focuses on how students should be taught rather than what they should be taught. This strive has been leading the educational sector over the past, several years. Wlodkowski (1978) highlights motivation and will to learn which overcomes in significance learning itself, as they provide the drive for learning. For Gee (2003) motivation is the basic element for students and for the sense of learning. Prensky (2002) claims that game playing is engaging, as opposed to the typical process which can be quite painful. Further building upon the motivation discussion, Garris, Ahlers, and Driskell (2002) noted that effective learning is achieved through effective engagement, which in the case of games is easier to reach. On the other hand, Gros (2007) stresses out the fact that a game needs to be also educationally appropriate, as just motivation is never enough.

Kiili (2005) argues upon games' educational benefits which include the provision of challenges related to a main learning task, and Oblinger (2006) points out the importance of the way a game is used. He stated that learners through games should (a) be engaged with the subject theories, (b) acquire knowledge via autonomous and discovery learning, (c) cultivate thinking skills, (d) learn how to learn (metacognition), (e) interact and communicate, and (f) operate as active producers of knowledge.

Kim, Park, and Baek (2009) compare game playing to problem-solving which at the extent can facilitate metacognitive strategies like self-recording, modeling, and thinking aloud. This complies with contemporary learning theories which suggest that learners construct their knowledge through experiential and reflective activities (Vygotsky, 1978), individually or collaboratively. This may also include inquiry and research (De Jong, 2006), might take place within authentic problem-solving situations (Anderson, Reder, & Simon, 1996), and can be incorporated via virtual environments (Dede, 2009).

Kandroudi, Bratitsis, and Lambropoulos (2014) examined the literature for identifying principles for designing games which comply with this constructivist approach, including adaptation and assessment (Moreno, Burgos, Martínez-Ortiz, Sierra, & Fernández-Manjón, 2008); curiosity, resonance, flow, goals, and expected value (Schell, 2008); and curriculum integration and learning objectives (Dillenbourg & Jermann, 2010). This "literature review" led to the creation of the LiX framework for educational digital game design (Kandroudi et al., 2014; Kandroudi & Bratitsis, 2016) which is graphically presented in Fig. 13.1. It consists of two parts, pedagogical and game elements. The former includes all the elements to consider when designing a game which are connected to the pedagogy that the game is set to serve, including content delivery, cognitive and metacognitive processes, mental and behavioral processes, learning goals, collaboration, and players' social interaction. The game elements are merely of a technical nature, including user interface, technology, levels of difficulty, gamification elements, and gameplay issues.

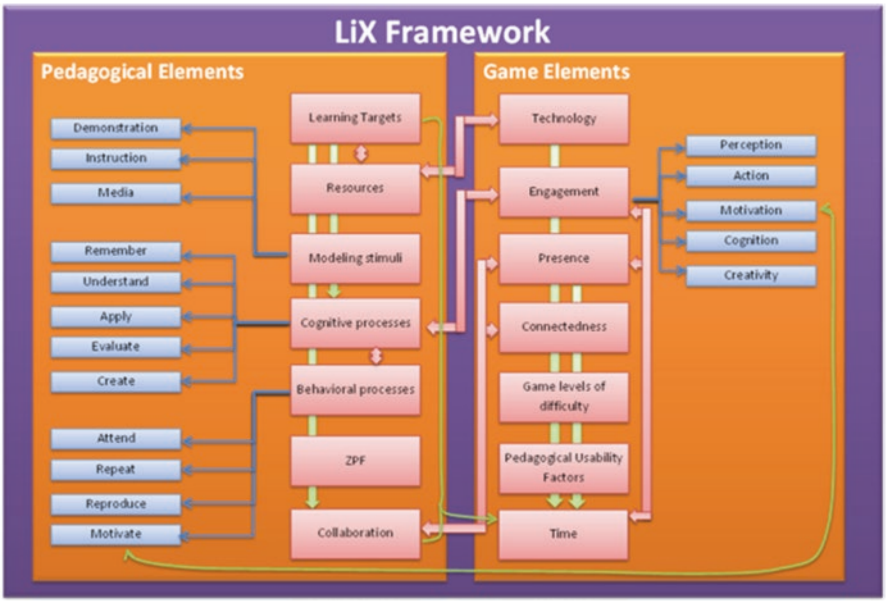

Fig. 13.1 The LiX digital game design framework

The framework is explained in detail in Kandroudi et al. (2014), and Kandroudi and Bratitsis (2016).

Citizenship Education: The WeAreEurope Framework

This section presents a brief literature review regarding citizenship education which led to the creation of a framework to support the learning content design by identifying the corresponding key competences to be treated through the game.

Focusing on terminology, citizenship is a notion, historically connected to the membership privileges within some kind of community. Thus, a certain status corresponds to equal participation in decision-making and regulation processes of social life (Bellamy, 2008). Although Cesarani and Fulbrook (2003) state that common understanding of belonging is raised in all communities, over the years the qualities of a citizen have been altered. For example, in Ancient Greece citizenship was related to law, gender, and class; in Rome it was based on common ideas (Bellamy, 2008) and later to the right to reside in the country of birth (Cesarani & Fulbrook, 2003). Over the past century, equality, structural inclusion, and diversity due to migration have arisen as important aspects.

The literature includes either citizenship theories which define the "ideal citizen" (normative theories) or explains sets of rights and duties for them (empirical theories) (Bellamy, 2008). All these result to sets of components which can be summed up to (e.g., Bellamy, 2008; Marshall & Bollomore, 1991; Ruud, 1997) (a) membership and sense of belonging, (b) rights and obligations, (c) (active) participation, and (d) diversity and respect. Further focusing on the EU level, heterogeneity is a fundamental characteristic of various community-related aspects, like ethnicity, religion, age, and gender. Although further complicating the definition of EU citizenship, the deriving diversity is considered as a source of strength for the EU. "While national citizenships presuppose peoples' rootedness, EU citizenship is intimately linked to citizens' mobility and border crossings. Mobility has personal and collective dimensions" (EC, 2013). Overall, the notion of citizenship entails a set of rights, obligations, rules, and possibilities which support the sustainability of a rather diverse community, allowing interconnection, interdependence, and interaction.

Nowadays, citizenship education (CE) is part of the curricula of many member states of the EU (Eurydice, 2012). Following the contemporary approach which defines competences as sets of knowledge, skills, and attitudes/values, the aim is to prepare the student to become a useful future citizen while also stimulating participation (EU, 2006; Ruud, 1997). A review of the curricula revealed that mainly a mix of interdisciplinary and discipline-integrated approaches are followed, enhanced by the facilitation of students' active participation inside and outside school. Generally, citizenship curricula cover a wide and very comprehensive range of topics, addressing the fundamental principles of democratic societies and contemporary societal issues, as well as the European and international dimensions (Eurydice, 2012).

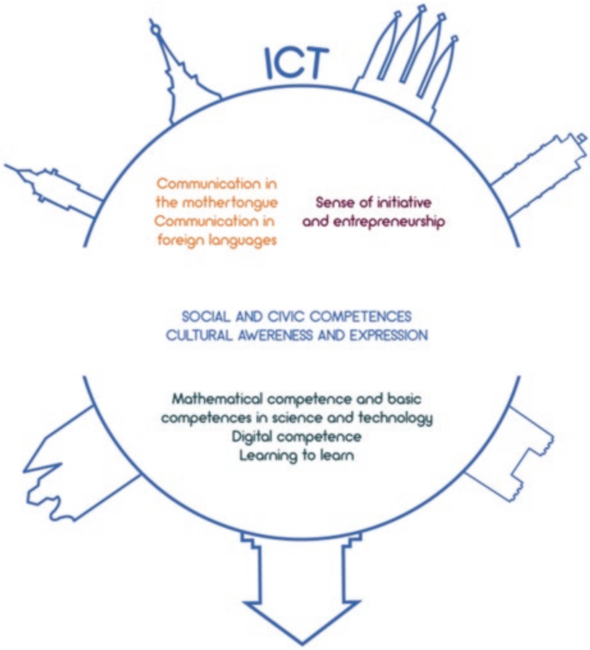

Fig. 13.2 EU citizenship key competence framework

Examining all the aforementioned approaches and combining the findings with the European framework for key competences (CIDREE/DVO, 2008) and also considering the twenty-first century skill set, a theoretical framework for the key competences for EU citizenship was constructed (Fig. 13.2). The framework considers the shift toward values such as respect for others and social justice (Lee, 2012) and keeps up with UNESCO's four pillars on learning (UNESCO, 2014). The official, detailed version of the framework can be retrieved form http://wreurope.eu/.

The WeAreEurope Game

WeAreEurope is an innovative online educational game for European CE which provides a challenging environment for young children (6–10 years old.) to (a) learn what it means to be a EU citizen, the rights and obligations that come with it, and how to participate in the EU at different levels; (b) learn about several aspects of the EU and of the member states—political, economic, and historic, among other aspects; (c) learn about diversity and how to benefit from a culturally diverse environment; and (d) exercise and develop transversal competences, including important entrepreneurial skills, like creativity, communication, teamwork, ICT, etc.

Following some of the serious games' design principles, it is not purely entertaining but integrates features like (Werbach, 2014) (a) adequate scenarios and a well-constructed storyline to enhance engagement, (b) a journey for the player to facilitate goal setting and motivation, (c) an environment customizable by the player, (d) balanced difficulty level and choices to enhance playability, (e) fun elements, and (f) a social dimension for facilitating players' interaction. It is free and online, thus platform independent, in order for it to be used easily in school settings, considering the technological limitations often seen in schools.

Game Description

The main characters are four children at the age level of the target group, each holding different expertise. These are the persons of letters; the mathematician; the scientist who answers to challenges related to literacy, mathematics, and sciences, respectively; and the adventurer who conducts team movements (Fig. 13.3). During the game registration, the players have to elect the wise one, using whatever method they agree on. This way, children are integrated into citizenship-related activities from the very beginning (elections, giving power to an individual). Players can involve other team members for solving challenges, but their decision can be overrun by the wise, who also answers the quizzes, also requesting the team's assistance at will. Thus, the design encourages the game to be played by a team of four (or multiples of 4), all working together toward a common final goal.

The players inadvertently go back in time and have to work their way to the present. During their journey, they visit distinctive periods in European history, each representing a game level: (a) The Dawn of Citizenship, (b) The Middle Ages, (c) The Age of Discoveries and Renaissance, (d) The Industrial Revolution, (e) The Twentieth-Century World Wars, and (f) My Europe. In each historic period, they have to travel through countries/territories and solve challenges, riddles, and quizzes. The main game objective is to reach the present time, using the minimum of turns.

Figure 13.4 presents one of the game maps which are updated in each period to represent the designated era and depict the continent's changes. To acquire the "keys" for accessing the Time Portal, the players must travel between countries/territories (red dots in Fig. 13.4) corresponding to game turns. In each turn, players

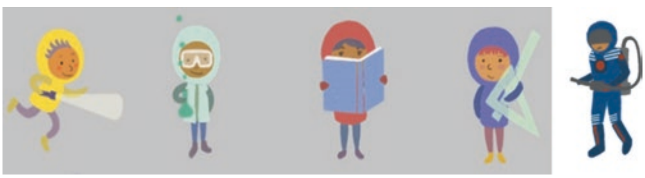

Fig. 13.3 The four main characters of the WeAreEurope game and a Time Agent

Fig. 13.4 "The Age of Discoveries" map

must solve a challenge of selected difficulty level (easy, medium, and hard) and also gaining points (weighted score). Then, a clue (new riddle) for the next map stop is presented. In case the players misinterpret clues and end up in the wrong country/territory, they are informed to reexamine the riddle and loose points.

A complementary character, an "old man," appears at the beginning (voice only), orientating the group as a narrator and providing help when requested. Opposing forces in the form of Time Agents attempt to prevent time travel by capturing the players while moving on the map. When caught, players have to prove that they belong to the designated time period by answering to a quiz (multiple-choice question). Failing to do so, they are sent back to the previous country/territory and lose a point. Players also get badges along the game by reaching certain milestones.

Other Gamification Features

Several additional gamification features have been integrated in WeAreEurope for increasing fun and engagement, which are briefly explained hereinafter.

Achievements correspond to the "keys" and thus milestones in the players' journey. They are connected to challenges and awarded with points (+5, +10, +20 according to the difficulty level). "5" points are deducted when failing to answer correctly to a quiz or to find the right destination. The lowest score is always "0," avoiding a frustrating negative score.

Challenges are introduced randomly via a database, making the game less predictable and more engaging. They cover topics of literacy, basic math, basic sciences, and others (e.g., geography, economics, nutrition/health) and must be primarily answered by the player of the corresponding role. The solution may require players to conduct research (e.g., in books, the Internet, etc.) and collaborate, thus being able to develop important transversal competences.

Riddles are clues that players must solve to find their next destination (country/territory), also randomly selected, ensuring players' engagement and interest.

Quizzes appear whenever players are caught by Time Agents (Fig. 13.3). They are time period-specific and also randomly selected from a predefined list, covering different aspects: history, geography, economy, and culture. Failing to answer them correctly leads to point deduction, and the players return to their last map stop.

Badges further enhance player status and are awarded for accomplishing achievements, allowing players to feel successful and rewarded regardless of their score. For example, the "Quiz 5" badge is awarded when answering correctly to five quizzes. These provide milestones for the players, increasing motivation to replay the game, as one can finish the game without receiving all the badges.

Complementary to the in-game activities (challenges, quizzes, and riddles), there are *landmarks* and *monuments* appearing on each map. For example in Fig. 13.4, the tower can be clicked to reveal information about them.

On a technical level, *music* and *sound effects* are relevant to each era and introduced depending on the environment the player is standing at each time (e.g., when entering a city). The goal is to help players identify historical periods and occasions by sound but also make the game more engaging. A *leaderboard* fosters competition among players. *Vocal narration* of the displayed text elements is available on request, allowing the game to be played by 6-year olds or even children with learning disorders which affect mainly reading. The game is delivered *online*, incorporating user control access and thus allowing record keeping.

Learning Activities

The main activities of the game are the challenges. Four (4) types are incorporate, namely, ordering, matching, fill-in, and non-digital ones. The first type requires from the players to order textual or graphical elements in an appropriate order (alphabetical, numerical, chronological, size, etc.). The matching challenges regard pair matching based on some feature (e.g., flags and countries, inventors and inventions, etc.). The fill-in challenges regard a text with missing phrases or an image with missing parts which can be filled using the drag-and-drop approach. All the challenges are connected with one disciplinary area of the framework (Fig. 13.2) and incorporate two aspects, information/knowledge provision and request for research conduction, thus allowing the students to acquire and search for new knowledge. The non-digital challenges do not have a definite answer, but rather a supervising teacher must respond yes/no to the satisfactory fulfillment of the activity tasks by the students. They involve in-classroom actions like story crafting, storytelling, theatrical play, or artifact construction.

All the challenges correspond to one of the basic competence groups (Fig. 13.2) and are appropriate for the target group's age. Furthermore, an equally important issue is to define the role of the educator while exploiting the game. Complying with contemporary theories, he/she is required to facilitate the inquiry and knowledge construction process of the students on a varying level of intervention, based on their cognitive level.

Implementation Guide: Game Deployment

In order to further facilitate the classroom integration of the game, an implementation guide (IG) was created. It is a freely available document which includes simple guidelines about the possible ways of engaging students and creating an effective experience for them. The IG is divided into two sections.

The first section provides instructions and ideas about group formation based on the classroom composition and role assignment ideas. The second section exemplifies two *modes* of playing the game in a classroom. Mode 1 exploits the game as an evaluation tool by requiring the students to apply already acquired knowledge from other learning activities in order to proceed in the game. In a matter of speech, the game is treated as a sophisticated knowledge test of the students' performance and can be played individually or in groups. Mode 2 proposes that the game serves as a basis or a trigger for extended activities, like group discussions or projects. In this case, a project can be built upon a single element of the game (e.g., a landmark appearing on the map or the correct answer to a challenge) or even a whole time period of the game, in various disciplinary areas.

The IG serves as a guide and thus cannot contain all the possible ways of exploiting the game. Instead, it provides a template for structuring a complete lesson plan (Fig. 13.5) and various examples of ready to apply lesson plans, thus providing the teachers practical information for immediate exploitation of the game. The underlying idea was to provide a structured way of describing the numerous teaching ideas which can evolve from the game and to allow the teachers who wish to exploit it to present their own ideas and share them with colleagues. For this reason, a blog platform which can be used for the exchange of lesson plans, teaching and exploitation ideas, but also for the exchange of comments and feedback from real case studies, among teachers all over Europe, is being built at the moment. Thus, the plan is to create a small community of practice (CoP) based on the game. This decision was based on the consideration that the educators should have the freedom to easily adapt teaching through this game to the actual needs and potential of their classes.

Lesson Plan #(Number)	
Title	*Identification Title* (Approach description. Game element on which the lesson is based – *Brief description*.)
Cognitive areas	• Enlist the cognitive areas which are involved
Equipment	• Describe the necessary equipment (if any. E.g. computers, markers, cartons, etc.)
Sources	Online & other sources which can be used (e.g. a book, a website)
Method	Description of the method
Existing knowledge	• Describe any prerequisite knowledge
Teaching/learning goals	Describe the teaching/learning goals, involving the following areas Discipline based ICT based Learning process based
The plan	Detailed description of the intermediate steps for realizing the lesson plan, including indicative durations

Fig. 13.5 Lesson Plan description template

Compliance with the Framework

As stated in the second section of this chapter, a framework for designing educational digital games (Kandroudi et al., 2014) was followed. In this section, the main aspects of that framework and the compliance of the game with them are examined.

Firstly, focusing on the pedagogical elements, the learning targets derive from the framework for the key competences (Fig. 13.2) which is based on the EU member states official curricula and an extensive literature review. Also, the correspondence with the curricula was later verified by the teachers who tested the game. The available resources were multiple, including books, textbooks, the Internet, and in-game information. The player is introduced to the game by a story narration at the beginning of the game and each time period (Modeling Stimuli: Instruction, Multimedia). Regarding the involved cognitive processes, the game is based on problem-solving, inquiry learning, and information retrieval/processing. The children utilize these approaches to eventually construct their own knowledge.

As far as behavioral processes are concerned, children are motivated through the game (this factor was extensively evaluated in a later phase) and are required to attend the virtual world of the game through their assigned roles and the corresponding characters. Collaboration is a key factor for the WeAreEurope game, throughout all its duration, as mainly it was designed to be played by groups or whole classrooms. Through this collaboration, the Zone of Proximal Flow (ZPF)

(Lambropoulos & Mystakides, 2012) is triggered, enhancing creativity (applied in artifact construction, information processing, and other in-game activities) and broadening the perceptions of the children about the notion of EU citizenship and the European dimension of their social lives.

Examining the game elements, the necessary technology is the web, and thus the game is platform independent, whereas no specific technical knowledge is required to install and use it. The player engagement occurs in various levels, requiring from him/her to act, perceive, apply old knowledge, and construct new but also be entertained and creative. The player is able to project him/herself by undertaking roles and controlling game characters with whom he/she can feel attached, as they are children of the same age. Players can connect themselves with their classmates when collaboratively playing the game or even other classes, by playing the game through the Internet. Regarding the pedagogical usability factors, the setting of the game is based on allowing the student to learn how to learn, thus applying various corresponding factors. Lastly, the time factor has two dimensions: the real time which is required to fulfill the necessary tasks and the simulated time in the game when traveling on the map and through time periods.

Table 13.1 sums up how the game follows the LiX framework. The reader can further understand all the factors by studying the framework in Kandroudi et al. (2014), Kandroudi and Bratitsis (2016), and Lambropoulos and Mystakides (2012).

Table 13.1 Correspondence of game to the LiX framework elements

Element	Description
Pedagogical elements	
Learning targets	Defined by the framework and the curricula
Resources	Game, the internet, books
Modeling stimuli	Instruction, media
Cognitive processes	Inquiry learning and problem-solving—Information processing
Behavioral processes	Attend and motivate
ZPF	Through group work
Collaboration	Throughout the game, role assignment, outside the game
Game elements	
Technology	Web based, free game, platform independent
Engagement	Perception broadening, intensive action, high motivation, cognition (knowledge construction), creativity (information retrieval and filtering, experiential learning)
Presence	By assuming player roles to which the child feels close too. Roles are clear
Connectedness	Through collaboration, intra- and inter-classroom
Levels of difficulty	Implemented various levels
Pedagogical usability factors	Cognition, metacognition, knowledge construction
Time	Real-time problem-solving, simulated in the game (time periods and traveling on the map), realistic

Pilot Testing and First Results

Having created the game and the accompanying material, the next step was to pilot test its effectiveness, in real classroom settings. The pilots were divided into two phases. In Phase 1, the teachers were familiarized with the game concept, scope, and mechanics but also the IG and the lesson plans in a 4–8-h training session. They were required to provide feedback about all the aspects of the game through a structured questionnaire, including the appropriateness of the learning content.

In Phase 2 they were asked to apply at least two of the lesson plans in the IG and design one of their own. These plans were to be evaluated by the design team and compared with the former in order to examine the proximity of perceptions between the designers and the in-service teachers. Feedback from the in-class realization of the activities was also provided via questionnaires and observation journals, including any technical or other problems, misconceptions of the students, and also the realism of the proposed lesson plans, focusing on the time needed to complete them.

The gamification elements were to be assessed by both teachers and students, through random, semi-structured interviews. The latter was considered as more appropriate for the ages of the students. The collected feedback was analyzed in order to facilitate the implementation of the game's and the complementary material final versions. Some indicative results are presented briefly hereinafter.

A total of 43 teachers and 88 students from 4 countries (Greece, Italy, Poland, and Portugal) were involved in the tests. Regarding Phase 1, the profiles of the teachers were recorded through the questionnaires, revealing that most of them had at least basic and only one had poor ICT skills. Only two were frequent digital game players, and the majority had played electronic games only a handful of times in total. The vast majority had no previous experience in exploiting games and software in the classroom. Mainly the Polish teachers were using educational software for math teaching. Finally, the background of almost all the teachers was high, holding at least a MSc degree.

Most of the respondents found the game very creative, although slightly complex at first. They considered that to play the game, skills are more required by the player than luck ($N = 6.67$ $SD = 2.14$—10-point scale). In all the questions about how much they liked the game, how engaging, interesting, and fun it was, they provided positive feedback (N between 6.1 and 6.7 SD close to 2.5). An interestingly positive answer was provided to the question "how much did the game cause you to interact with other players" ($N = 7.9$ $SD = 1.9$). Overall, most of them were very engaged with the game, enjoyed playing with it, and stated that they would play it again and recommend it to their colleagues.

Regarding the IG, similar findings were revealed. Thus, they rated the included ideas and lesson plans in a positive manner and considered them applicable in class. It is important to note that when asked "Which was the most interesting part of the IG," almost half of them mentioned the provided lesson plans which they considered very helpful. Also, other qualitative aspects of the game (e.g., playability, user interface, technical soundness) and the complementary documents were evaluated in order to be later corrected if necessary.

In Phase 2 and after exploiting the game in their classrooms, they reported that their students were much more engaged with the game than they were in Phase 1. They reported their students being very concentrated on their tasks (even more than usually), commenting upon the fun factor of the game and declaring their preference to play it collaboratively. About 60% of the teachers claimed that their students did acquire new knowledge through the game but that they also improved their way of collaboration, based on their observations. Regarding the lesson plans, they stated that the IG was very helpful, also for helping them create their own lesson plans. Overall, excluding some minor problems, mainly of a technical nature, they didn't make any improvement suggestions. On the contrary they said that they would change anything in the game and activities' design.

Regarding the students, the distribution was 60% boys and 40% girls, and they were almost equally distributed regarding their age. Overall, they seemed more enthusiastic than their teachers and rated most of the aspects of the game with an average of about two points higher than the rating of the teachers. Apart from minor technical problems, they highlighted the collaboration feature, the fun of the game, and the game story. About 85% of them claimed that they had learned about the EU and citizenship, with almost all of them (89%) stating that they would recommend the game to their friends. On a more amusing side of this study, when asked if they needed anything else, many of them said that they would like their schools to take them on educational trips to the cities which were the map stops in the game.

Overall, the feedback from the pilot testing of the WeAreEurope game was very positive by all the involved end users, although the students were slightly more enthusiastic. Some necessary minor improvements were highlighted through these tests, mainly of a technical nature. Also, some teachers felt that many of the challenges were slightly difficult for the 6-year olds and proposed that the designers include some easier ones in order to not frustrate that age group.

Discussion

In this chapter, an online game for teaching EU citizenship key competences to 6–10-year-old students was presented, revealing all the intermediate steps of the design of an educational game. Attempting to recap, the first step should be an extensive literature review of the core discipline in order to perform something similar to the user needs of any product. This would allow the definition of the learning goals of the game, forming a theoretical framework. A brief description of the corresponding framework (Fig. 13.2) is presented in this work.

The next step would be to start actually designing the game which should incorporate two features, being a serious game. The first one is that of entertainment; after all it is a game. The second is that of serving an additional purpose, learning in this case. Attempting to enumerate the design aspects to be considered, they are learning objectives' definition, learning delivery method, role of the educator, players' evaluation elements, game overall concept, gamification elements, and technical considerations. The overall game concept includes gameplay, storyboard of the game, game goal definition, and timeline (setting, route, and ending). The gamification elements relate to the motivation, entertainment, and the engaging factors of a game. In this case, a ranking and a grading procedure is introduced. Point acquisition and milestone reaching processes are designed, along with rewards and goals. Technical aspects include graphic and user interface design, along with sound and visual effects which should also be considered.

Much of the game design was based on the gamification approach of Werbach (2014), also matching the LiX Framework which was proposed by one of the partners (Kandroudi et al., 2014) and taking into account the target age group and its peculiarities. The main gamification features concerned engagement, sense of presence, various levels of difficulty, a solid timeline, appropriate technology, and pedagogical usability factors (Kandroudi et al., 2014). Whereas some of these elements are self-explanatory if one reads the frameworks (e.g., an online, HTML5-based game is a good choice to create a platform-independent product with no sophisticated technological demands), some choices can be further justified. In matters of engagement, action takes place in a context where the children can feel attached to. The main characters are their age, and no gender information is apparent (children wear hoods—Fig. 13.2). There is a sense of adventure (time travel); children understand clearly where they stand within the game (presence), and they are required to act. Action results in problems (mainly of a cognitive nature) which must be solved. Much of the action takes place outside of the game (research, argumentation, construction, performance, etc.), and thus creativity, perception, and cognition are challenged. Motivation is influenced by elements like the badges, the achievements, the variety of problems (challenges, quizzes, and riddles), and the adaptability of the game. A child (or a group) can play the game in various ways by altering collaboration protocols, group sizes and formation, and difficulty level. Since this is a game aiming at full integration with the curriculum, these issues are of great importance as it becomes flexible for the students but the teachers as well.

Further examining the pedagogical element collaboration is served in multiple ways; various resources are available in order to best serve the cognitive processes, according to Bloom's taxonomy (Kandroudi et al., 2014). It is important though to examine the teachers' perspective. The challenges (main game activity) are designed so as to provide flexibility and freedom to the teachers to create teaching activities which can be as complex as a long-term project (see IG section). Thus, the main statement that this game makes is that it acts less as a "learning game" and more as a "teacher's facilitation tool" which would support CE by allowing inquiry and problem−/project-based learning to take place in class.

Preliminary observations thus far indicate that the teachers reacted very positively in the game concept and its class-applicability, as it can be exploited for various disciplines which already exist within the curricula. The overall idea seems to fit the setting and the contextualization of the classrooms of the target ages. Some minor technical problems need to be addressed (e.g., multi-browser support), and a difficulty downgrade for the lower end of the age group seems more appropriate. The cognitive capability varies significantly in this age span. The students seemed very enthusiastic and engaged in the gameplay, although characters' movement was not easy for the 6-year-olds and needs adjustment. But overall, preliminary observations indicate that the education aspect of the game is well served. It is to be noted that the pilot testing approach presented in this chapter is of a great importance, as the game was tested in real classroom settings, involving many stakeholders (both teachers and children). The two-phase design of feedback collection allowed for the better acquisition of their perspectives, mainly because it allowed the feedback collection from the teachers' side before and after having to work with the game in their classrooms. Any possible differences at that point return valuable information for a game designer. Initially, he/she can focus more precisely on how to engage the teachers more effectively, prior to deploying the game in the classrooms. After all, if the teachers are not persuaded about the educational value of such a game, eventually it will not reach the classrooms. Then, the informational needs of the teacher in order to assist them in exploiting the game for their teaching practices are recorded more clearly and treated accordingly. Of course, the end users (children) must always hold a significant role in testing such a digital product.

Overall, this chapter intended to present a step-by-step, game design process, serving as a practical guide for such attempts. Relying on the collaboration between theory treating academics, practice oriented in-service teachers, and the enterprise which aims at designing sustainable products and also from a financial point of view, it does not follow an ordinary theoretical presentation format, incorporating added value within this context, as it aims to present the practical perspective.

Toward the game's sustainability, the designers decided to facilitate the creation of a European-wide community of practice (CoP), attempting to involve teachers and students from various countries. The CoP will allow lesson plan and exploitation idea exchange among teachers but also scores, solutions, and other ideas among students. When designing a digital product, reaching the availability stage is never enough. Proper attention to its sustainability should be paid. In this case, for reaching an adequate critical mass, an organization of a European-wide competition among students as individuals, whole classrooms, and even teachers will be organized. For example, the highest game score, the best lesson plan, and the most inventive story created as part on a non-digital challenge are some of the elements to compete for. The consortium is already planning two multiplier events toward the project's end to disseminate results and announce the competitions' winners, expecting to reach the CoP sustainability goal through them. Nowadays, social media and the numerous events (scientific or not) provide fertile ground for disseminating similar products, even if they concern teachers who attempt to exploit a commercial digital game in their classrooms. To say the least, this chapter highlighted the importance of feedback collection and experience exchange.

Concluding, this chapter described the lifespan of an EU-funded project which aimed at designing, implementing, and eventually deploying freely an online educational game regarding a disciplinary area of great importance for the educational sector. Through this process, the aim was to use it as an example in order to practically explain how one can start from an idea and eventually reach the point of deploying a complete product which has the potential to reach the classrooms and actually function in real reaching settings.

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Chapter 14
Evaluation of an Augmented Reality Game for Environmental Education: "Save Elli, Save the Environment"

George Koutromanos, Filippos Tzortzoglou, and Alivisos Sofos

Introduction

In recent years, technological evolutions and advances in mobile devices (i.e., smartphones and tablets) and in telecommunications have brought enormous changes in learning, resulting in what we call "mobile learning" (e.g., Han & Shin, 2017), "ubiquitous" (e.g., Kong, Chen, Huang, & Luo, 2017) or "seamless" learning (Wong & Looi, 2011), and "here-and-now mobile learning" (Martin & Ertzberger, 2013). Empirical evidence shows that mobile learning can support students in learning various subjects, such as mathematics, science, art, and history (Crompton, Burke, & Gregory, 2017).

An integral part of this learning process on mobile devices is digital games (Koutromanos & Avraamidou, 2014). An area that requires particular research attention on mobile devices, because of its advantages is the augmented reality games (AR) (Kasapakis & Gavalas, 2015; Ruiz-Ariza, Casuso, Suarez-Manzano, & Martínez-Lopez, 2018). The use of AR games in these devices can positively influence learning, participation, and development of various students' skills (e.g., Koutromanos, Sofos, & Avraamidou, 2015). Recent examples of AR games include Pokémon GO (Ruiz-Ariza et al., 2018) and Ingress (Davis, 2017). For instance, Ruiz-Ariza et al. (2018) in their study found that Pokémon GO increases the amount of daily exercise in adolescents, could positively affect their cognitive performance, and improve the social relationships.

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During the past few years, several AR games for learning have been developed and tested through empirical studies (Kasapakis & Gavalas, 2015; Koutromanos, Sofos, et al., 2015). Within the literature, we can find examples on the use of location-based AR games for environmental education such as the "Environmental Detectives" (Klopfer & Squire, 2008) and the "Mad City Mystery" (Squire & Jan, 2007). For example, "Mad City Mystery" is an AR game which was applied in University of Wisconsin venues near Lake Mendota. The game is about solving a mysterious death of a man who was fishing in the lake. Students in groups and in cooperation with others interview, study documents, and collect various data. Previous research has shown that these mobile games can help students to increase their environmental knowledge and their motivation to engage in learning activities (e.g., Kamarainen et al., 2013; Klopfer & Squire, 2008; Squire & Jan, 2007). Despite the interest in AR games in environmental education, the potential of AR in this research area remains unexplored.

Based on the above brief introduction, the aim of this study was to evaluate the AR game "Save Elli! Save the Environment!" which is played outdoors in Santorini and refers to its environmental problems. This study is part of the formative evaluation of the game. Its objectives were (1) to examine students' acceptance of the game and their intention to play it again, (2) to study students' use of the game, and (3) to identify the hindering or facilitating factors of the use of the game.

The paper is structured as follows. The definition of AR and AR games is shown first. Then, the literature review regarding the AR games in environmental education is presented. Later the design of the game and the methodology of the evaluation are presented. Then, the results of the evaluation of the game are reported. The rest of the paper presents the main conclusions including limitations and future research directions.

Augmented Reality Games

The term "augmented reality" (AR) has been defined differently among researchers in computer sciences and educational technology. According to Carmigniani and Furht (2011), AR is defined as an indirect or real-time view of a physical real-world environment that has been augmented by adding virtual information to it. Azuma (1997) defines AR as a system that has three main features: (a) it combines real and virtual objects; (b) it provides opportunities for real-time interaction; and (c) it provides accurate registration of three-dimensional virtual and real objects.

Nowadays, mobile devices, such as smartphones and tablets, have become a fruitful platform through which to apply AR technologies. According to Squire and Jan (2007), AR games are games that are played in the real world with the support of mobile devices (e.g., mobile phones), which create an imaginary world in the real world. Location-based augmented reality games (e.g., historical and geographic locations, etc.) use data from a wireless network and/or GPS to determine the location of the device in the area and to augment the real environment with digital objects (e.g., images, audio, video, 3D, etc.) (Cheng & Tsai, 2013; Squire & Jan, 2007). Laine (2018) defines mobile AR as a type of AR where a smartphone or tablet is used to display and interact with virtual content (e.g., 3D models, annotations, videos), which are overlaid on top of a real-time camera feed of the real world. According to Kasapakis and Gavalas (2015), AR games can be classified as a subcategory of pervasive games.

Augmented Reality and Environmental Education

There has been, until now, an increasing number of studies that focus, inter alia, on the use and impact of augmented reality (AR) in various subject fields, such as mathematics (Estapa & Nadolny, 2015), language learning (Hsu, 2017; Wang, 2017), engineering (Costa & Arsenio, 2015), art (Daponte, De Vito, Picariello, & Riccio, 2015), and natural sciences (Chen & Liao, 2015). There are only a few studies regarding environmental education and AR, smartphones, tablets, and PDAs that are presented below. They focus on primary and secondary education and are related with AR applications or games which are mainly used in informal learning environments and outdoor areas.

Squire and Jan (2007) created and implemented "Mad City Mystery," an AR game for PDA devices, taking place in the environment of a natural lake. The aim of the game was to study the impact of the playful AR on the students' scientific thinking and argumentation on environmental issues. The findings of the study conducted on 28 primary and high school students showed that AR games can enhance students' scientific thinking and the development of arguments regarding environmental issues.

In an effort to explore the prospect of pedagogical exploitation of AR games and their design methodology, Klopfer and Squire (2008) developed a platform for the construction of educational AR games in order to support learning related to environmental education. In their research they applied "Environmental Detectives," an AR game for PDA devices tested by groups of university and high school students outdoors. The data gathered from five case studies provided important information regarding the design and technological, methodological, and pedagogical aspects of the implementation of the AR and have shown that it can be successfully used as a learning tool in informal learning environments.

Folta (2010) examined the effect of the AR game "Red Wolf Caper" in the learning process and the interest of 81 high school students for environmental education. Through the game, the students were asked to select different scientist roles and to clear up the mystery of the game by visiting specific locations and interviewing virtual characters via PDA devices. The study showed that the game had a positive impact on the understanding of concepts related to the subject, while the students considered their overall experience with the AR as a positive one. In another study, Zarzuela, Pernas, Martínez, Ortega, and Rodríguez (2013) created an AR game on mobile phones and tablets to enhance students' learning on animals. The pilot implementation to 25 primary school students showed that, through interaction with virtual animals and digital information relating to them, the game had a positive effect on the acquisition of knowledge by students.

Kamarainen et al. (2013) combined the AR technology with water sampling tools (PH, temperature, oxygen) to create "EcoMOBILE." In this game, users moved themselves to selected lake locations by conducting sampling checks for water quality and characteristics. The instructions for each location were given through AR on their mobile device (PDA). The sample consisted of 71 primary school students. The results showed that the program had a positive impact on the understanding of concepts of the lake environment, while it also engaged students to scientific methods of data measurement and analysis. In a similar research, Chiang, Yang, and Hwang (2014) created an AR system for tablets to conduct exploratory outdoor learning activities. The purpose of their experiment was to examine the effectiveness of this approach to student knowledge in a lesson on aquatic ecosystems. The sample consisted of 57 primary school students of the fourth grade. The results showed that the implementation of AR can improve students' learning outcomes, while at the same time it can enhance the concentration on the lesson. Finally, Hwang, Wu, Chen, and Tu (2015) created an AR game with quick response codes on mobile phones to enhance students' observability in the natural environment. The game consisted of a series of missions in which students were asked to locate the digital image displayed by means of fast response codes in the natural environment. The sample of the survey consisted of 57 primary school students of the fifth grade. The results showed that an AR game could enhance students' knowledge, as well as their attitudes toward excursions to the natural environment.

The Game "Save Elli! Save the Environment!"

Game Design

The game was designed in three stages. Stage 1 included the identification of the problem of environmental protection on the island of Santorini, the teaching necessity of engaging students in it, and the identification of the added value of the AR in the game. Additionally, a literature review for similar studies was conducted, part of which was presented in the previous section. In order to determine the theoretical framework of the game, the learning theories were studied in Stage 2, and the scenario and its content were designed based on certain characteristics of the situated learning theory (e.g., authentic experiences), constructivism (e.g., collaboration among learners), and behaviorism (e.g., game evaluation section). At Stage 3, the content of the game was evaluated by two educational technology specialists in terms of usability and by two teachers in terms of its content.

Description of the Game

The purpose of the game “Save Elli! Save the Environment” is that students of the last three grades of primary school explore the environmental problems of the island of Santorini, adopt positive attitudes toward environmental issues on the island, propose solutions for improving the quality of life and the development of their land, and finally develop ways and skills of intervention in their immediate social environment to address the problems of the wider environment. For this purpose, five locations with real environmental issues were selected. These were (1) the Greek Public Power Corporation’s lignite plant, (2) the sanitary landfill of Thira, (3) the Sea Diamond shipwreck, (4) the much frequented by tourists’ beach of Kamari, and (5) a recycling bin area near the school. These locations were either within walking distance of school or provided clear visual contact from the point the game was taking place.

The scenario of the game asks students, in groups of five, to save a small sea turtle, Elli, from a wicked scientist whose purpose is to destroy the environment of Santorini. At the time of her abduction, Elli leaves five clues at the above five locations of the island to guide the students to the scientist’s laboratory. These five clues compose the five-digit code that, at the end of the game, releases Elli from the lab of the bad scientist. Each of the five locations was augmented with two kinds of digital material, which appeared automatically when the students entered the geographical boundaries of the selected area: (a) the ecological problem, enhanced with digital information (image, video, or website) and (b) a multiple-choice question related to the environmental problem. To earn the clue of each area, students had to collect and process information from the digital material and from the physical environment through a worksheet so as to answer correctly the question that followed. By answering the questions correctly, students could discover the secret code that released Elli and successfully complete game. The game is played on tablets (iOS operating system). Examples of game screens are shown in Fig. 14.1.

Fig. 14.1 Examples of game screens

The ARIS Augmented Reality Platform

The AR game "Save Elli! Save the Environment" was built on an open-source, location-based game platform called ARIS (augmented reality for interactive storytelling). It is an AR open-source platform for mobile devices that support iOS operating system.

Methodology

This study employed a case study approach. To evaluate the acceptance of AR game and get some suggestions and comments from students, a questionnaire was designed building on previous studies of technology acceptance models (see Ajzen, 2006; Davis, 1993; Koutromanos, Styliaras, & Cristodoulou, 2015). In order to understand students' opinions and explain their use of AR game, qualitative data from observations and interview were collected.

The Sample

Forty students (22 boys, 18 girls) from two classes of the fourth grade of the Primary School of Pyrgos, Thira, Santorini, participated in this study. Twenty two (55%) of them said they had their own tablet, while 18 (45%) used their family's or relatives' and friends' tablet. 82.5% ($N = 33$) said they were playing games on a tablet. The two class teachers were men, both with 7 years of teaching experience, and they often used the tablets that were available at school.

Data Collection

A questionnaire was used to evaluate AR game acceptance. It consisted of three items that measured students' intention/preference to play the game again (e.g., *I wish to continue playing the game "Save Elli" the next school year with my classmates*) (Cronbach's $a = 0.89$), four items measuring the perceived ease of use of the game (e.g., *It's easy for me to remember how to play the game "Save Elli"*) (Cronbach's $a = 0.91$), three that measured the perceived usefulness of the game (e.g., *The game "Save Elli" makes the lesson at school better*) (Cronbach's $a = 0.79$), and four that measured the social influence (e.g., *My friends think I have to play the game "Save Elli"*). These items were measured on a five-point Likert scale (1 = strongly disagree to 5 = strongly agree) and were based on the technology acceptance model (Davis, 1993).

There were also four items that measured the perceived enjoyment from the game (e.g., *It's exciting to play the game "Save Elli"*) (Cronbach's $a = 0.86$); these items were adapted from the Koo research (2009). Additionally, attitudes toward the use of the game were measured on a five-point semantic differential bipolar scale (1–5) and four pairs of adjectives (e.g., *I find playing the game "Save Elli" with my class: boring/interesting, unpleasant/pleasant, bad/good, useless/useful*) (Cronbach's $a = 0.68$). This section was based on the theory of planned behavior (Ajzen, 2006).

Additionally, data were collected through observation and interviews to study how students played the game in the group they belonged, as well as to identify the factors that hinder or facilitate their use.

The Procedure

The study was conducted in May 2015. The game was played by eight groups of five students each. Each group started the game from school accompanied by their classroom teacher, who had previously received instructions on how the game is played and the locations/missions to follow. In each of the five locations/missions, students were watching the augmented material on the tablet and sought to find the right answers to the questions that were appearing.

At the same time, during the game, they were completing a worksheet on the environmental problem of the location as a group (e.g., identification and causes of the problem). The average completion time of the game for each group was 50–70 min, and the whole procedure took place in 1 day. None of the groups played the game at the same time in the same location but with a difference of several hours. The role of each teacher was limited to resolving technical problems (e.g., no Internet connection). Each group of students, upon its return to school the next day, completed the worksheet by proposing solutions to limit or address the environmental problem of each location they visited. Finally, all groups discussed together their experiences regarding the environmental problems they identified, and through various activities (e.g., collage, posters), they suggested specific actions for the implementation of the solutions they proposed. All groups were ranked according to whether they managed to save Elli (i.e., the number of the clues of the secret code they had collected). Finally, they completed the questionnaire mentioned in the previous section, while additionally, eight students (one from each group) participated in an interview.

Data Analysis

The questionnaire data were analyzed in SPSS (v. 21). Cronbach's alpha, descriptive analysis, Pearson correlations (two-tailed), and hierarchical regression analysis were implemented. The qualitative data of observation and interviews were encoded to enrich the findings of the quantitative analysis and to highlight aspects that arise from them.

Results

The results of the descriptive statistics showed that the students' attitudes toward the use of the game had mean score of 3.79 (SD = 0.679), perceived usefulness had mean score of 3.77 (SD = 0.619), perceived ease of use had mean score of 3.27 (SD = 0.883), perceived enjoyment had mean score of 3.71 (SD = 0.693), the social influence had mean score of 3.46 (SD = 0.825), and intention to use the game had mean score of 3.58 (SD = 0.806). The results of the Pearson correlations showed that students' intention to play the game was positively correlated, in descending order, with perceived enjoyment ($r = 0.647$, $p = 0.000$), social influence ($r = 0.576$, $p = 0.000$), perceived usefulness ($r = 0.521$, $p = 0.001$), and attitude ($r = 0.468$, $p = 0.002$). In turn, the attitude was positively correlated with perceived usefulness ($r = 0.549$, $p = 0.000$). Perceived ease of use of the game was not correlated with perceived usefulness ($r = 0.278$, $p = 0.082$) nor with the attitude ($r = 0.282$, $p = 0.078$). Hierarchical regression analysis showed that perceived usefulness (*beta* = 0.549, $t = 4.045$, $p = 0.000$) explained 28.3% of the variance in attitude ($F = 16.365$, $p = 0.000$). Finally, the variables of attitude, social influence, perceived usefulness, and enjoyment explained 45.5% of the variance in students' intention to play the game again ($F = 9.143$, $p = 0.000$). However, perceived enjoyment was the only variable influencing intention (*beta* = 0.573, $t = 2.519$, $p = 0.016$).

The data from student observation during the game and from the interviews in the classroom largely confirmed the above results as to the ease of use of the game on the tablet and the enjoyment they experienced due to it. Looking for secret codes through the observation of their environment and the study of augmented material students increased the interest in environmental education. In fact, some students showed more interest in engaging and collaborating with other members than that they showed in their classic classroom activities. In addition, various interactions were developed among the members of each group, which, according to the student interviews, helped them to successfully complete the game and make it more interesting. These interactions can be categorized as follows: (1) asking questions about the additional digital material understanding, (2) expressing disagreement/agreement with the opinions of the other members, and (3) formulating ideas on the correct answer to the questions on the tablet and the worksheet. Finally, individual problems were observed which resulted in the interruption of the game for a very short time. They had to do with the sudden Internet breakdown, the failure to locate the exact position of some locations via GPS, the difficulty in hearing the sounds of the game due to other sounds in the environment, as well as the difficulty in viewing the screen of the tablet due to intense sunshine.

Conclusions

This study evaluated the AR game "Save Elli! Save the Environment!" and focused on the following objectives: (1) to examine students' acceptance of the game and their intention to play it again, (2) to study the students' use of the game, and (3) to identify the hindering or facilitating factors of the use of game. In terms of the first objective, the empirical results of this study demonstrated that the students generally had positive attitudes toward the use of the AR game “Save Elli! Save the Environment,” felt that their environment welcomed this use (i.e., social influence) and that the game was easy and useful in learning, and enjoyed it. The results indicated that students’ attitudes toward the game, social influence, perceived usefulness, perceived ease of use, and perceived enjoyment are able to explain 45.5% of the variance of students’ intention to play the AR game. However, only perceived enjoyment had an impact on the intention. This fact indicates that students probably prefer to play the game again, having as a strong incentive the enjoyment they will get from it. Also, the fact that it was found that the perceived ease of use did not affect at all the attitude but only its perceived usefulness probably means that the students have a positive attitude toward the game not because they find it easy to play but useful in their learning process.

In terms of the second objective, the empirical results of this study indicated that the AR game was used by the students in their groups with great ease and enjoyment. During the game, various interactions were developed among the team members; these interactions enhanced cooperation with each other and increased the interest in learning. These results are in line with those reported in the recent reviews of the literature on AR (Akçayır & Akçayır, 2017) and AR games (Koutromanos, Sofos, et al., 2015). In terms of the third objective, the results showed that technical problems, such as the Internet and GPS, as well as problems due to the environment (e.g., strong winds, intense sunshine), make it difficult to read the contents on the screen of the tablet and listen to audio files. The results of this study are in line with those of Crandall et al. (2015), Dunleavy, Dede, and Mitchell (2009), and Klopfer and Squire (2008).

In conclusion, it can be said that the AR game of this study is suitable for environmental education in terms of design (i.e., ease of use) and content (i.e., useful). Future research should examine the effect of the game on students’ knowledge and their attitudes towards environmental problems in order to determine the added value of the AR in learning.

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Chapter 15
Mobile Games in Computer Science Education: Current State and Proposal of a Mobile Game Design that Incorporates Physical Activity

Ioannis Siakavaras, Marina Papastergiou, and Nikos Comoutos

Introduction

The success of the digital gaming industry, young people's great attraction to digital games, the belief that such games can serve learning, and the emergence of powerful and user-friendly game creation tools are factors that have contributed to the development of research on digital educational games (Martens, Diener, & Malo, 2008). Malone (1980) has highlighted the relationship between internal motivation and learning and has argued that curiosity, fantasy, and challenge are basic elements that motivate the players of digital games and, thus, should be taken into account in the design of digital educational games. Prensky (2001) has defined the following structural elements of digital games: rules, objective, narrative, conflict and antagonism, feedback and results, as well as interaction of the player with the world of the game and/or other players. He maintained that those elements should be included in an educational digital game, in order to make it more engaging.

Digital game-based learning can coexist with other forms of learning in all educational levels and in various subjects with a view to motivating students and improving the educational process (Jong, Shang, & Lee, 2010; Kazimoglu, Kiernan, Bacon, & Mackinnon, 2012). Research on its effectiveness has reported positive learning outcomes (e.g., Kordaki, 2011; Papastergiou, 2009; Sitzmann, 2011). Digital game-based learning can also contribute to the adoption of constructivist approaches which emphasize student's activity and problem-solving (Jong et al., 2010; Kazimoglu et al., 2012).

Technological advances in the area of mobility have led to the broad adoption of mobile devices (smartphones and tablets) that have considerable processing power

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and storage capacity together with multimedia capabilities. Millions of users install and play digital games on their mobile devices, and the international turnover of the mobile game industry is constantly increasing (ESA, 2014). The new features of mobile devices, which are not found on desktop computers, contribute toward the success of mobile games and are particularly interesting for educators and researchers (Lee, 2005). Specifically, contemporary mobile devices comprise a GPS receiver, an accelerometer, and other sensors, through which they can gather information from the player's environment, such as the player's position and movements (through the accelerometer and GPS) (Liu, Zhu, Holroyd, & Seng, 2011). It is, thus, possible to develop games that are context-aware. Dynamic information derived from the player's environment can be transferred in the game in real time and can determine the player's interaction and progress in the game. This new possibility can further increase players' engagement in the game and, in cases where the game is educational, could also perhaps improve learning outcomes (Liu et al., 2011). Furthermore, mobile games offer opportunities for anytime/anyplace, self-directed learning, thus, contributing to bridging the gap between formal learning that takes place in school/university and informal learning that takes place in students' free time (Lee, 2005).

Mobile games, thus, constitute promising tools for learning. The aim of this study was to pinpoint the possibilities and perspectives that mobile games offer to computer science education. In the study, prior research on the utilization of mobile games in computer science education is first summarized. Then, a type of context-aware game, namely, location-based games (LBGs), is presented together with various platforms for creating LBGs, which can be utilized by computer science educators. Finally, a research in progress, aimed at the creation and evaluation of an LBG for the learning of concepts related to safe Internet use, is presented.

Mobile Games in Computer Science Education

From October 2015 to January 2016, scientific articles published in or after 2005 were searched for in bibliographic databases (Scopus, ScienceDirect, Springer, IEEE Xplore, Google Scholar) using the keywords mobile games, learning, education, informatics, programming, and computer science. The nine studies that were located and which fulfilled the inclusion criterion concerning the utilization of mobile games for the teaching of computer science (or programming concepts) in school or university education are presented in Table 15.1. It should be noted that articles referring to studies that focused on the learning of programming through engaging students in mobile game development were excluded (i.e., only studies in which students were the users, and not the developers, of mobile games were taken into account).

Four studies are concerned with the learning of fundamental computer science concepts, hardware topics, and security topics. An adventure game for learning hardware terms and understanding the functions of the motherboard is presented in

Table 15.1 Utilization of mobile games in computer science education

Article	Game name	Target group	Mobile platform	Learning topic
Fotouhi-Ghazvini, Earnshaw, Robison, and Excell (2009)	MOBO City	University students	Android	Computer hardware
Arachchilage, Love, and Maple (2013)	Antiphising Game	University students	Android	Internet security
Giannakas, Kambourakis, and Gritzalis (2015)	CyberAware	Primary school students	Android, iOS	Internet security
Lovaszova and Palmarova (2013)	Not mentioned	Primary and lower secondary school students	Windows Phone	Fundamental computer science concepts
Hamid and Fung (2007)	SpaceOut, Doggy, Snail	University students	Not mentioned	Programming
Yoon et al. (2013)	DeBugger	University students	Android, iOS	Programming
Jordine, Liang, and Ihler (2014)	Java Tower Defense	University students	Android	Programming
Zhang and Lu (2014)	iPlayCode	University students	iOS	Programming
Shellington, Humphries, Morsi, and Rizvi (2015)	Syntax Circuitry	Upper secondary school students—University students	Android	Programming

the first study (Fotouhi-Ghazvini et al., 2009). The game world is the motherboard "town" with its various areas (e.g., CPU) and the corresponding electronic circuits. The basic game characters are a bus and its driver (the operating system). The player moves within the fantastic world interacting with the objects that they encounter and answers questions with a view to helping the bus reach its destination and completing its task (e.g., to correctly transfer data from the scanner port to the screen). An evaluation of the game with 15 computer science students, which was conducted through observations and a knowledge questionnaire, showed that the game promoted motivation for learning and understanding of technical concepts. The second study (Arachchilage et al., 2013) was conducted with 40 university students and staff members, who used a mobile game for their training to protect themselves against phishing attacks. The aim of the game was for the player to learn to recognize and avoid suspicious URLs and suspicious e-mail messages. The main character was a fish that had to avoid fishermen's suspicious bait. Each piece of bait was connected with a URL (or an e-mail message). The fish had to bite only the bait that represented valid URLs and e-mail messages (rejecting the fraudulent bait) before its time expired. The participants who had played the game were very satisfied and showed significantly greater improvement in the practical phishing attack recognition test compared to the participants who had used an equivalent educational website. Cybersecurity is the topic of another mobile game (Giannakas et al., 2015), within which primary school students had to successfully play mini-games on online security and privacy to be awarded a "cyber awareness" certificate. An evaluation of the game with 43 students, conducted through pretest/posttest questionnaires, showed that the game was usable and satisfactory for them while also improving their cybersecurity knowledge.

In the fourth study (Lovaszova & Palmarova, 2013), LBGs not specifically designed for computer science education were used to introduce 13 primary and lower secondary school students to fundamental computer science concepts (e.g., the stack structure and the graph concept). One of the LBGs was based on a folk tale and required the player to complete a series of tasks with the following limitation: no task could be completed before the completion of its nested subtask. In another LBG the player had to move on the ground so that their body delineated a single-pinned house in different ways. The school students played the LBGs outdoors, in groups. The conducted observations and interviews revealed that it was a pleasant experience that helped students understand both the stack structure and the graph concept and familiarize themselves with GPS technology.

The remaining five studies concerned the teaching of programming mainly to university students. Hamid and Fung (2007) present a set of puzzle- and arcade-type mobile games (SpaceOut, Doggy, Snail) aimed at testing students' knowledge of the C++ programming language. Players had to find the correct answers to programming questions or to correctly arrange lines of code. The games were evaluated (through questionnaires) on interface design, attractiveness, and addictiveness. The 50 participating students found the games satisfactory, overall. DeBugger (Yoon et al., 2013) is a multiplayer online role-playing game (MMORPG) targeted at introducing computer science students to programming through a set of mini-games (e.g., correctly order code segments, calculate the values of variables, etc.) and a virtual community of peers (for cooperation in answering programming questions). Its evaluation through pretest/posttest involving 29 students assigned to an experimental and a control group showed a significant improvement in programming knowledge for the experimental group. Through a game of learning Java programming (Jordine et al., 2014), the player has to defend a fortress by implementing a Java class to define a tower in Java code. The code is checked, and if it is correct, the player passes to the next level, where they have to initialize their tower and to place it in the virtual space, within which the enemy is also moving. The player should appropriately program their tower so that the enemy is blocked. Comparison of students' performances is possible through a leaderboard. However, as in Hamid and Fung (2007), no evaluation results are mentioned. The fourth study (Shellington et al., 2015) concerned a game for training in the basic syntax of the C, C++, and Java languages (variable declaration, selection, and repetition structures). The aim is to learn to locate syntax errors easily. Bubbles containing code segments flow on the screen, and the player has to break the bubbles that contain syntactically erroneous code and leave the rest of the bubbles intact. A results screen, a leaderboard, and various difficulty levels are supported. An evaluation of the game with 13 students, conducted through questionnaires, showed that the game improved students' ability to discern between correct and erroneous syntax. In addition, the students liked the game. A similar game for learning the syntax of the C++ programming language is presented in Zhang and Lu (2014). Code segments appear to the player, who has to tag them as syntactically correct or erroneous within a specific time frame, gaining or losing points accordingly. High-scoring performances are rewarded with medals. The evaluation of the game with 36 students showed that it was enjoyable, although learning outcomes were not assessed.

As deduced from the above-presented review of the literature, research on the utilization of mobile games in computer science education is still limited. The results of the few studies that were found and which comprised an evaluation of mobile games converge in that the games used spurred the motivation of students and conferred positive learning outcomes. Those encouraging findings should be supported by further research. In addition, the review reveals that the aforementioned features of mobile devices that differentiate them from desktop computers (e.g., GPS, sensors) have not been taken into account in the design of the majority of the games used, with the exceptions of the study by Yoon et al. (2013), in which GPS was used for finding peers nearby, and the study in which LBGs were used (Lovaszova & Palmarova, 2013). However, those LBGs had not been specifically designed for computer science education.

Location-Based Mobile Games

Contemporary mobile devices can track the user's geographical position while they are moving, so mobile games that process geospatial data are feasible (Lovaszova & Palmarova, 2013). A game is considered to be an LBG, if it requires the physical displacement of the player from location to location, and evolves according to the player's location (Avouris & Yiannoutsou, 2012). In LBGs there is a strong connection between physical and virtual activities. For instance, maps of real-world areas can serve as game maps (or game playgrounds) and can be linked to real or virtual objects that players have to collect, avoid, or interact with (Kamel Boulos & Yang, 2013). The popularity of LBGs has increased in recent years, as smartphones with GPS capabilities have become widely available (Althoff, White, & Horvitz, 2016).

LBGs can facilitate innovative, constructivist approaches to learning, placing users within meaningful, authentic activities which combine physical movement in outdoor spaces of the real world with exploration, problem-solving, and collaboration, supporting cognitive and social components of learning (Spikol & Milrad, 2008). Thus, players' physical activity could be encouraged (Althoff et al., 2016), together with the development of thinking, inquiry, problem-solving, communication, and collaboration skills (Barnett, Bangay, McKenzie, & Ridgers, 2013; Spikol & Milrad, 2008).

Platforms for the Creation of Location-Based Mobile Games

In what follows, four platforms for the creation of LBGs and augmented reality experiences are presented. Advances in mobile technologies have enabled the development of education-oriented game creation platforms with capabilities that can enrich the players' learning experiences (e.g., GPS, augmented reality). Three of the presented platforms (TaleBlazer, ARIS, Wherigo) are open-source and could be utilized by computer science educators.

TaleBlazer (http://taleblazer.org/), developed at MIT, permits the creation of mobile games for Android or iOS and focuses on connecting learning with gaming and technology. Using an online authoring tool, one can create a game selecting the map where the game will take place and placing virtual characters (agents), with whom the player can interact with, on the map. The game evolves both in the real and in the virtual world. The connection between those worlds is determined based on the player's location in the real world, as tracked by GPS. The player walks around a physical area with the Taleblazer software installed on their mobile device. Their GPS location allows them to interact with nearby virtual objects.

ARIS (https://fielddaylab.org/make/aris/), developed at Wisconsin University, includes an online authoring tool for the creation of LBGs and interactive stories, and an app for iOS devices. The produced games can be played on such devices and are stored on the platform's servers (no downloading from App Store and installation on the player's device is needed). Using GPS and QR codes, players navigate a hybrid world with virtual characters and objects placed in the physical space (Aurelia, Raj, & Saleh, 2014).

7scenes (http://7scenes.com/) allows the creation of stories and LBGs that comprise images, video, and audio. An online authoring tool is offered, and the games which are produced can be played on Android or iOS mobile devices. As players walk around an area (with GPS enabled on their devices), various events are triggered. Players can actively participate by posting photos, comments, or suggestions and share those postings with other audiences through social media (Facebook, Twitter). Multimedia elements can be coupled with points of interest on a map, so that those elements appear when players reach the corresponding points (Spallazzo, Ceconello, & Lenz, 2011).

Wherigo (http://wherigofoundation.com/) also allows the creation of stories and LBGs. For instance, in a fictional adventure game, players can walk around specific places, perform tasks, as well as collect and use virtual or real objects. Games are created through an online authoring tool or through an authoring tool running on the author's PC and are played in the real world. The player should have an Android or iOS mobile device which is GPS enabled and should download the game file using the Wherigo software for mobile devices.

On Table 15.2, the four platforms are compared as to their support of various features.

As shown on Table 15.2, all four platforms allow the creation of games that assign different roles to players, incorporate various types of assessment (e.g., multiple choice, "fill-in the blank"), and "overlay" the physical space with interactive multimedia characters and objects. Fewer platforms offer the author the possi-

Table 15.2 Platforms for the creation of LBGs

Platform	Roles	Assessment support	Multimedia support	QR codes	Data selection	Open source	Multiplayer
TaleBlazer	✓	✓	✓	–	–	✓	–
ARIS	✓	✓	✓	✓	✓	✓	✓
7scenes	✓	✓	✓	✓	✓	–	✓
Wherigo	✓	✓	✓	–	–	✓	–

bility to incorporate QR codes into a game (which act as triggers for activating various media, such as video, 3D models, and webpages) or the capacity to store (on the mobile device or on a server) data that players may record (e.g., photos, audio) while browsing the physical space. Finally, currently, only two of the platforms support the creation of games for a large number of simultaneous players so that those players interact within a common world.

The Research in Progress: The Proposed Game Design

As deduced from the previous sections of this study, there is a need to design, develop, and evaluate games for computer science education that make use of the specific motivational features of contemporary mobile devices that hold potential for learning and which are not encountered on desktop computers, such as the possibility to track the player's position through GPS.

As mentioned, LBGs can play an important role in promoting both learning and physical activity (Barnett et al., 2013). Encouraging students' physical activity is a crucial issue today given that the number of overweight or obese young people is constantly rising due to bad nutritional habits and a lack of physical activity (Kosti & Panagiotakos, 2006). Furthermore, despite the fact that motion and cognition have been considered unrelated for decades, in recent years, many scientific studies support the positive connection between physical activity and cognitive function (and also emotional development and academic performance) highlighting the need to create learning environments that incorporate motor activities (Jensen, 2005).

The aim of the research in progress is the design, development, and evaluation of an augmented reality LBG for learning concepts relevant to safe Internet use. The game is targeted at upper secondary school students (for use in the students' free time) or at young adults. The proposed mobile game (Fig. 15.1), which is still in the design stage, is based on the geographical location and the environment of the player; it demands physical activity on behalf of the player, and it utilizes the player's movements (e.g., walking) as a basic component of the game mechanics. Principles of exploratory learning, the aforementioned specific capabilities of contemporary mobile devices, and the elements that (as mentioned in the "Introduction" section of this paper) should be included in an educational digital game (i.e., rules, immediate feedback, interaction, challenge) were taken into account in the design of the mobile game.

Fig. 15.1 The basic screen of the game

The game is intended to be used on a smartphone or a tablet running Android or iOS and follows a narrative model with phases evolving through information processing and problem-solving. Within the framework of the game, the player (or a pair of players that play in cooperation) undertakes the role of game characters, who face various security problems on the Internet. The problems, which are still in the design stage, address security issues related to electronic mail, web browsing, and social media. For instance, the player walks to a physical location such as a bank and is then asked questions—regarding the proper use of web banking credentials—by an avatar. In other locations, the player faces questions that challenge them to discern between a "legitimate" e-mail message and a spam message or a message that could harm their computational device. Satisfactory solutions to the problems posed add points to the player's score, whereas unsatisfactory answers detract points from the score. The non-player game characters are virtual avatars dispersed at various physical locations. The game will comprise various levels: at every game level, the player should encounter a specific number of such avatars and should solve the problems posed by those avatars.

Within the physical space, the players also have to discover and collect additional virtual objects, by walking to them. Those objects will be represented in augmented reality form, will be connected to specific physical locations, and will be available depending on the players' performance. Each object will provide information (e.g., documents, video clips) regarding Internet security issues (e.g., regarding the basic functions of a firewall or those of an antivirus program, regarding unsolicited e-mail, etc.), which the player has to process and utilize in order to solve the problems posed to them by the virtual avatars during their tour within the physical world.

Digital virtual agents will act as mentors, each time providing players with additional information regarding the specific problem that the players are asked to solve. For instance, if the problem that the player is facing is the proper selection of an access password for a website, the mentor provides tips regarding the selection of strong passwords. Mentors will be presented in augmented reality form and will be interspersed within the broader geographical area. Players should walk (using the GPS system) to each mentor's location (Fig. 15.2), which is indicated with a colored mark on the area map, in order to interact with the mentor and derive useful information from the mentor (Fig. 15.3). Players have to analyze and synthesize the various pieces of information that they gather within the game environment in order to utilize it to solve the problems and, thus, to advance in the game.

In order to unlock a game level and pass to the next level, the player should gather a specific number of points and should also cover a specific distance (in kilometers). Both the requested points and the distance in kilometers will increase from level to level, as the game level increases. In this way, it is intended that the educational objectives of the game (learning about Internet security issues through problem solving) are met and, at the same time, that the player's physical activity (specifically walking) is encouraged.

On the basic screen of the game, each player (or pair of players) is able to see the map of the area where the game takes place, their current position, and the kilometrical distance that they have covered. The possible actions that the player will be able to perform within the game will be grouped in a menu that will appear on the screen. Each player will also be able to see their activity in an activity log (Fig. 15.4). The scoring system of the game will be based on points that the player gains or loses depending on their achievement in problem-solving and their amount of physical activity (as deduced from the distance in kilometers covered) during the various phases of the game.

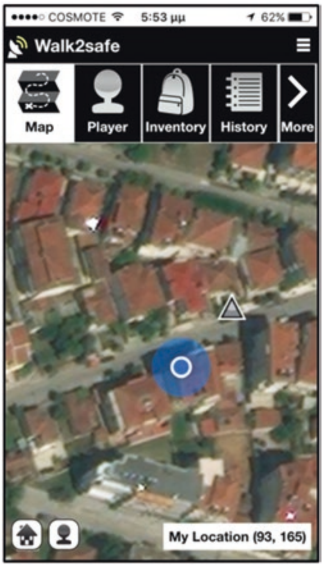

Fig. 15.2 The player is walking to an agent-mentor

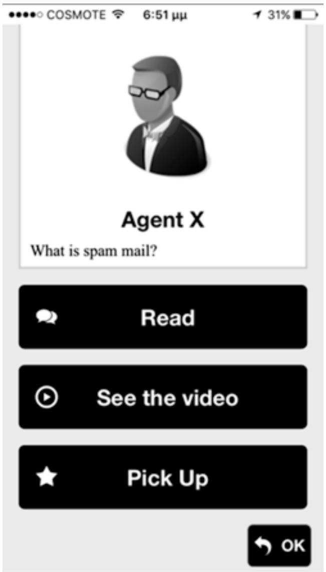

Fig. 15.3 Getting help from an agent-mentor

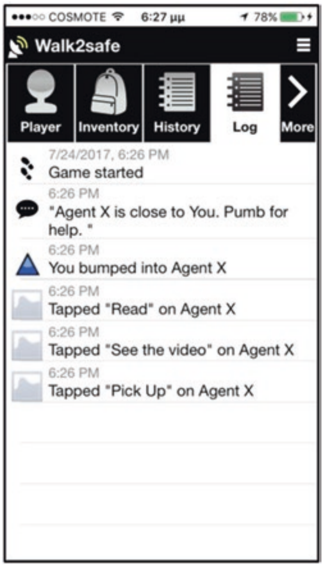

Fig. 15.4 The player's activity log

As already mentioned, support of collaborative learning is an intended feature of the game. Specifically, players will have the opportunity to collaborate in problem-solving within small groups (pairs), while the various different groups will compete. The group that manages to gain the highest score will be the winning group.

Finally, the game will allow customization so that it can be used in different geographical areas. The help system of the game will comprise instructions for new players as well as help regarding technical issues (such as setting the Wi-Fi/3G), which are necessary for the functioning of the game.

A first version of the LBG will be developed and pilot tested. Based on the pilot test findings, a new, improved version of the LBG will be created and evaluated. The main research questions that will guide the evaluation are: (a) Is the game accepted by the students (i.e., is it considered to be useful, usable, and engaging)? (b) Can the game improve students' knowledge regarding safe Internet use? and (c) Does the game have any impact on students' attitudes toward physical activity (and especially walking)? For the evaluation study—which will comprise pretest, intervention and posttest—the participants will be randomly split into two groups. The first group will use the LBG. The second group will use an alternative version of the LBG (simulated LBG—SLBG), which will differ from the LBG only in that it will not require physical movement, given that in that version, the physical movement of the student's body in the physical space will be substituted by movement of the student's fingers on the screen of the mobile device.

Closing Remark

As far as CS education is concerned, research on the utilization of mobile games for learning is still very scarce, and no LBG specifically created for CS education has been reported in the research literature. This study highlighted the new possibilities that mobile games offer to computer science education, overviewed the research conducted thus far in this area, and presented state-of-the-art technological tools for the creation of LBGs. It also reported on the design of a research in progress, which aims at the creation and evaluation of an LBG for learning about safe Internet use and which attempts to fill in the aforementioned gap in the research bibliography. It is hoped that the outcomes of this research offer useful guidance toward the introduction of mobile technology into CS education and also toward the integration of physical activity into academic subjects other than physical education, such as CS.

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Chapter 16
Examining Students' Actions While Experimenting with a Blended Combination of Physical Manipulatives and Virtual Manipulatives in Physics

George Olympiou and Zacharias C. Zacharia

Introduction

The number of studies concerning the use of Virtual Manipulatives (VM) and Physical Manipulatives (PM) in science has been increasing considerably in the last few years (Balamuralithara & Woods, 2009; deJong & Njoo, 1992; Olympiou & Zacharia, 2012; Olympiou, Zacharia, & de Jong, 2013; Zacharia, 2015; Zacharia, Olympiou, & Papaevripidou, 2008). To this end, many researchers have tried to document the value of using VM for the enhancement of students' learning in science, by comparing PM with VM in several domains. The discrepant results of these studies lead to the conclusion that the use of PM differs from the use of VM, because of their differing affordances. Given these differing affordances, many researchers have advocated in favor of combining the use of PM and VM (Jaakkola & Nurmi, 2008; Jaakkola, Nurmi, & Veermans, 2011; Toth, Morrow, & Ludvico, 2009; Winn et al., 2006; Yueh & Sheen, 2009; Zacharia et al., 2008; Zacharia & Constantinou, 2008; Zacharia & Olympiou, 2011), in order to combine the advantageous affordances that both PM and VM carry (Zacharia, 2015). Toward this goal, Olympiou and Zacharia (2012) developed a framework that portrays how PM and VM could be blended on the basis of their affordances for enhancing students' understanding of the subject domain. Several studies, using this particular framework, have shown that blended combinations could be conducive to students' understanding (e.g., Olympiou & Zacharia, 2012; Zacharia & Michael, 2016). However, none of these studies have looked into what differences emerge in discourse and actions that cause this differentiation in favor of the blended combinations of PM and VM, as opposed to PM alone. To this end, we decided to examine whether the use of blended combinations of PM and VM affects students' actions in a different manner than the actions followed by students using only PM.

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The purpose of this study was to go beyond the results of the extant comparative studies among PM and VM and combinations of PM and VM and investigate the experimental procedures and actions followed by the students when enacting experimentation with PM or a combination of PM and VM. The idea was to get an insight as to the reasons causing the differences in students' learning when using different manipulatives during experimentation. To this end, we set as our overarching goal the investigation of students' actions, while PM alone and a blended combination of PM and VM are set for experimenting in the physics domain of Light and Color. The blended combination was based upon the framework developed by Olympiou and Zacharia (2012).

Theoretical Background

Experimentation has been a central feature for science learning across several learning theories (e.g., active learning theory, constructivism). The idea is to transfer the scientist-science paradigm within class. For instance, the principles of the active learning theory (learn by doing), which entails students' active involvement in their learning process, are in total alignment with having students design and execute experiments for testing hypotheses or answering research questions. In fact, active learning approaches, such as discovery learning and inquiry-based instruction, involve experimentation in the process of science learning. The inquiry approach, which is the dominant learning approach (besides traditional lecturing) at the moment, portrays experimentation as one of the main ingredients of supporting students' science learning (van Joolingen & Zacharia, 2009).

Experimentation could be enacted through the use of different means (e.g., physical materials and apparatus, simulations, virtual reality, remote labs). For the purposes of this study, we focus only on physical manipulatives (the use of concrete materials and apparatus) and virtual manipulatives (the use of computer simulations with no haptic devices).

PM and VM

The added value of using PM and VM in science laboratory experimentation has been documented by many researchers in the literature, especially for enhancing students' conceptual understanding across several domains (Finkelstein et al., 2005; Henderson, Klemes, & Eshet, 2000; Hofstein & Lunetta, 2004; Hsu & Thomas, 2002; Jaakkola et al., 2011; Toth et al., 2009; Triona & Klahr, 2003; Winn et al., 2006; Zacharia, 2005, 2015; Zacharia & Anderson, 2003; Zacharia & Constantinou, 2008; Zacharia & Olympiou, 2011; Zacharia et al., 2008). Either alone or in combination, all studies showed improvement of students' learning/performance within their condition. However, in the cases where PM, VM, and their combinations were compared, mixed results occurred. In other words, the literature reports instances in which all means of experimentation were found to be more conducive to student learning than the other. At first, these findings appear to be discrepant to each other. However, a more detailed look of the methods followed, and the manipulatives used revealed that the differences emerged due to the differing affordances that PM or VM carry. Overall, the idea coming out of these findings is that the mean of experimentation that carries a unique affordance (i.e., not carried by the other means), which favors the fulfilment of the learning goal at hand, will be the one to surpass the impact of the other means.

In the literature, a number of such PM and VM affordances are reported (e.g., Huppert, Lomask, & Lazarowitz, 2002; Klahr, Triona, & Williams, 2007; Olympiou & Zacharia, 2012; Zacharia, 2015). For example, in the case of PM, physicality (actual and active touch of concrete material) is reported as one unique affordance (see Zacharia, Papaevripidou, & Loizou, 2012). Students' learn how to handle concrete, physical materials and apparatus and develop the relevant tactile skills required for their proper use (Gire et al., 2010). Another PM affordance is that measurement errors are present by nature, whereas in virtual environments measurement errors are often ignored. In other words, through the use of PM, students come to understand the real, "messy" nature of the world and the existence of measurement errors, which need to be considered and dealt with for correcting the data collected through an experiment (Toth et al., 2009).

In the case of VM, a larger number of unique affordances exist than in the case of PM (Ronen & Eliahu, 2000; Smetana & Bell, 2012; Trundle & Bell, 2010). VM were created to complement the insufficiencies of PM experimentation, which resulted in a vast number of VM unique affordances. For example, in VM environments reality parameters could be altered (e.g., accelerate, decelerate, and freeze time), simplified (e.g., remove errors), or be "augmented" (e.g., add vector representations). Moreover, VM allow manipulation of variables which would be impossible to change in the natural world (e.g., remove all trees from planet earth to study the effects on climate), offer immediate feedback in case of errors during setting or executing an experiment and offer scaffolding to support students during experimentation (for more details see Olympiou & Zacharia, 2012).

Blending PM and VM

Given the differing unique affordances of PM and VM, several researchers have argued in favor of blending PM and VM together in order to take advantages of as many unique affordances as possible (Olympiou & Zacharia, 2012; Winn et al., 2006). In fact, Olympiou and Zacharia (2012) developed and tested a framework for blending PM and VM in an attempt to optimize student learning through experimentation. Findings revealed that the framework was successful in enhancing students' performance (e.g., Olympiou & Zacharia, 2012; Zacharia & Michael, 2016). However, no research was conducted for identifying the reason behind the blended combinations' success over PM and VM alone conditions. In general, there is a lack of research in investigating the differences emerging through the use of PM or VM by studying students' discourse and actions. Such research is crucial in order to explain the differences in performance identified in prior research. For instance, are students' actions different when experimenting with a blended combination of PM and VM and PM or VM alone? If yes, in what respect? What are the aspects of students' actions causing the variation in performance?

This Study

This study aimed at investigating the similarities or differences between students' actions, who used either PM alone or a combination of PM with VM (PMVM) for conducting the study's experiments. For coding students' actions while experimenting, we analyzed (a) the kind of activity that is routinely defined by the curriculum material; (b) students' actions across each of the study's experiments by using a particular coding scheme (see Scherr, 2008; Scherr & Hammer, 2009); (c) classroom talk and questions based on a framework describing different types of questions regarding procedures followed during the experimental setup, as well as the scientific content of the study; and (d) the scientific accuracy of students' predictions, observations, and explanations for each of the study's experiments.

The study was contextualized through the *Physics by Inquiry* curriculum (McDermott & The Physics Education Group, 1996) aiming to compare the experimental procedures/actions taking place during undergraduate students' laboratory experimentation in the domain of Light and Color. Two conditions were involved in the study's research design, namely, the PM alone condition and the blended PMVM condition. Blending PM and VM was based upon the Olympiou and Zacharia (2012) framework developed for combining PM with VM, for developing conceptual understanding.

The main purpose of this study was to compare students' actions between the two conditions in order to identify the reasons behind the superiority of the PMVM condition in enhancing students' conceptual understanding than the PM alone condition. We found in a previous research of ours that the PMVM condition had statistically significant higher mean scores than the PM alone condition (Olympiou & Zacharia, 2012). Specifically, we aimed at answering the following research question:

- How do the experimental procedures/actions that students follow differ when the students experiment with PM and a blended combination of PM and VM?

Methods

Sample

The participants of the study were 15 (freshmen) undergraduate students of a university in Cyprus who were enrolled in an introductory physics course that was based upon the Physics by Inquiry curriculum (McDermott & The Physics Education Group, 1996). The sample was drown randomly from a sample of 70 undergraduate students (see Olympiou & Zacharia, 2012). The 15 participants were randomly separated into two conditions, namely, the PM alone condition (seven students) and the PM and VM blended combination condition (PMVM condition; eight students). None of the participants had taken college physics prior to the study. The students in all conditions were randomly assigned to groups (three or four persons in each group) as suggested by the curriculum of the study (McDermott & The Physics Education Group, 1996).

Curriculum Materials

In this study, we used the chapter of Light and Color of the Physics by Inquiry curriculum (McDermott & The Physics Education Group, 1996). The success of the Physics by Inquiry curriculum is grounded on three foundational components that were found to support conceptual understanding, namely, inquiry, socioconstructivism, and the POE (predict-observe-explain) strategy (see Zacharia et al., 2008). For the purposes of this study, we selected two experiments from the section of colored light. Specifically, we selected:

- Experiment 4.1: An introductory experiment, which guides students to conduct several mixtures of colored light, in an attempt to understand how to combine light of different colors to obtain a particular color of light and differentiate colored light from colored paint.
- Experiment 4.4: An experiment introducing the use of color acetates and prisms when mixing colored light in front of a screen.

The two experiments were purposefully selected, because they included all the main procedures and concepts of the content to be learned. Through these experiments, the students were encouraged to develop a mental model that would enable them to predict what the color of an object will be when viewed under the light of different colors or through colored acetates.

Material

Physical Manipulatives

PM involved the use of physical instruments (e.g., rulers), objects (e.g., cubes), and materials (e.g., lamps, torches, different color acetates, projectors) in a conventional physics laboratory. During PM experimentation, feedback was available to the students through the behavior of the actual system (e.g., a colored shape on a screen) and through the instruments that were used to monitor the experimental setup (e.g., rulers, screens).

Virtual Manipulatives

VM involved the use of virtual instruments (e.g., rulers), objects (e.g., cubes), and materials (e.g., lamps, torches, different color filters, projectors) to conduct the study's experiments on a computer. In the case of the PMVM condition, a part of both experiments analyzed was conducted through the virtual laboratory *Optilab* (see Fig. 16.1) (Hatzikraniotis, Bisdikian, Barbas, & Psillos, 2007). Optilab was selected because of the fact that it retained the features and interactions of the domain of Light and Color, as PM did. The software offered feedback throughout the conduct of the experiment by presenting information (e.g., distance, color) through the displays of the software. No feedback was provided by the software during the setup of an experiment.

Despite the fact that PM and VM provided analogous feedback to students, VM carried additional affordances in comparison to PM. For instance, VM (at the PMVM condition) offered feedback on the outcome color (i.e., the name of the

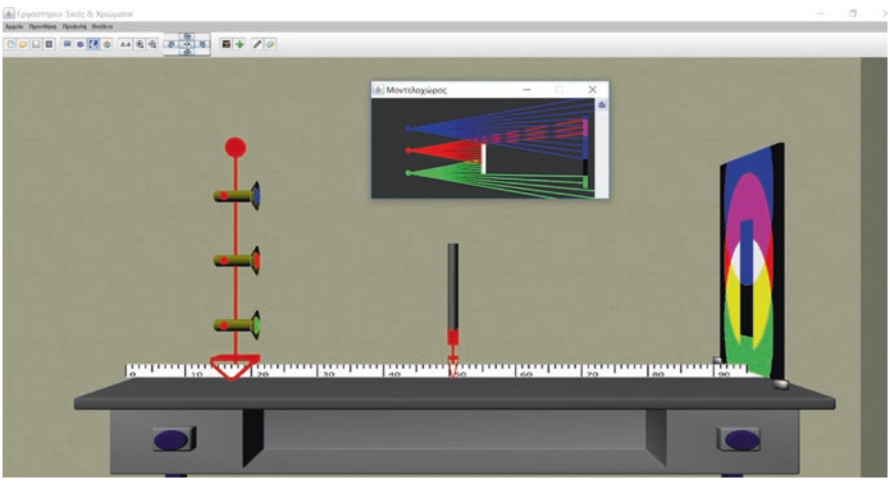

Fig. 16.1 The *Optilab* environment

color) of any experiment that involved combining colored light. Additionally, the VM offered ray diagrams.

Procedure

All participants were introduced to the Physics by Inquiry curriculum by engaging in the treatment of the condition they belonged to. All students in both conditions were familiarized with the material and the instruments that were going to be used (either PM or VM) before the study's treatment and completed all of the Light and Color sections before the one at task.

In general, the procedures followed in both experiments, according to the Physics by Inquiry approach were somewhat the same, namely, (i) students' experimentation with different beams of colored light, colored acetates, and prisms, (ii) categorization of results in primary and secondary colors of light and their behavior under specific circumstances (e.g., under white or green or red color, etc.), and (iii) students' conclusions based on their explanations and discussion of their results with the instructors.

The role of the instructor was critical. It is supportive in nature and requires instructors' engagement in dialogues with the students of a group at particular points of the activity sequence, as specified by the Physics by Inquiry curriculum. Both conditions shared the same instructors. All instructors were previously trained in implementing the Physics by Inquiry curriculum and had experienced its implementation at least for 2 years.

The duration of the whole study was 13 weeks. Although, the two experiments we focused for the purposes of this chapter lasted 2 weeks. All conditions were facilitated in the same laboratory environment that hosts both conventional equipment and a computer network arranged at the periphery. Students met once a week for one and a half hour. The time-on-task was the same for all conditions.

Data Collection

The data collection involved videotaping students' actions and discussions while experimenting in both conditions (PM and PMVM), as well as collecting reflective journals of instructors during the intervention. In the PMVM condition, a screen-captured data software was also used for the purposes of the study. Whole group videotaped conversations were used as the primary data source for this chapter. Previous work was focusing on assessing students' performance through the use of conceptual tests (e.g., Olympiou & Zacharia, 2012; Zacharia & Michael, 2016). Hence, no information was provided in those studies on what type of students' actions or procedures were taking place when students were using blended combinations of PM and VM. Such information is important in order to identify the possible reasons behind students' differences in test performance. For the purposes of this study, we investigated whole group student conversations in the context of experimenting with PM or a blended combination of PM and VM in order to capture students' actions. We also used instructors' reflective journals for enriching our data and for triangulation purposes.

Instructors' Reflective Journals

All instructors kept a reflective journal in which they had to document and reflect upon a group's (a) difficulties when setting up and conducting an experiment, (b) conceptual understanding related problems while conducting an experiment, and (c) level of understanding of colored light concepts per experiment. Finally, the instructors were asked to reflect on any additional actions made by the students, which were not included in the curriculum material.

Video Data

The video data collection involved videotaping two groups of students from each condition, throughout the study. All four groups were randomly selected. In the case of PM, we used two camcorders: one focusing on students' faces for recording their conversations and the other on the lab bench to capture their experiment setups. In the case of VM (PMVM condition), we used one camcorder and a screen capture software. The camcorder was used to videotape students' conversations, and the screen capture plus video-audio software (River Past Screen Recorder Pro) was used to capture their computer work activity.

We intentionally selected and analyzed the aforementioned experiments of the colored light section. These experiments were selected because the students of the two conditions were found to have statistical significant differences in their scores on a conceptual test. Specifically, the PMVM students were found to have higher scores than the PM alone students (Olympiou & Zacharia, 2012). Thus, the idea was to examine whether this difference in test performance could be associated to possible differences in the student actions during the PMVM and PM alone experimentation.

We located the video excerpts of the two specific experiments in both conditions and proceeded with transcribing the corresponding dialogues of students' group work (data collected through camcorder 1) and with coding students' actions (data collected through camcorder 2 or the screen capture software). Our unit of analysis was single-student utterances, each of which was analyzed separately and received only one code. All student conversations were analyzed, corresponding to eight meetings overall (two meetings in each group of each condition).

Data Analysis

The data analysis focused on identifying patterns in the verbal exchanges of the learners from the ground up, as well as patterns in their actions during experimentation. We developed a coding scheme for coding both utterances and experimentation procedures carried out by students, as well as the students' interactions with the instructors in each condition, applied either by students or instructors or by the curriculum material.

For the development of the coding scheme used for this purpose, we first identified similar studies in which students' group work in science was analyzed, based on specific coding schemes. Specifically, the coding scheme emerged in this study was based on research studies focusing on students' interaction as well as on instructors' questioning and providing feedback to students in science group activities (see Chin, 2006; Conlin, Gupta, Scherr, & Hammer, 2007; Scherr, 2008; Scherr & Hammer, 2009). At the same time, a conscious effort was made to investigate students' group work in inquiry-based experimentation environments (e.g., Redish & Steinberg, 1999), in order to define the main steps of strategies used in such learning environments, especially the ones based upon the Physics by Inquiry curriculum (e.g., POE strategy). We then run a pilot study videotaping three groups experimenting with the Physics by Inquiry curriculum in the domain of Light and Color (one in each condition, PM and a combination of PMVM), in order to apply the categories of the coding scheme that emerged through the literature. This way, we paid close attention to student talk and the experimental procedures followed in the same

Table 16.1 The students' actions coding scheme

Category	Codes
Who is talking	(a) the students, (b) the instructor
Dialogue components	(a) Questions regarding scientific content, (b) scientifically accepted answers, (c) scientifically not accepted answers, (d) scientifically accepted statements, (e) scientifically not accepted statements, (f) comments about scientific content, (g) reading instructions, (h) irrelevant comments, (i) procedural comments, (j) questions regarding the experimental procedures, (k) scientifically accepted answers regarding the experimental procedure, (l) scientifically not accepted answers regarding the experimental procedure, (m) comments regarding the experimental procedure
Predictions	(a) Scientifically accepted prediction based on previous experiment, (b) scientifically not accepted prediction based on previous experiment, (c) scientifically accepted prediction based on previous knowledge, (d) scientifically not accepted prediction based on previous knowledge
Explanations	(a) Scientifically accepted explanation based on previous experiment, (b) scientifically not accepted explanation based on previous experiment, (c) scientifically accepted explanation based on previous knowledge, (d) scientifically not accepted explanation based on previous knowledge, (e) scientifically accepted explanation based on the experiment at task, (f) scientifically not accepted explanation based on the experiment at task

environment like the one used in this study, without losing the details emerging through the different condition experimentation (PM and PMVM). As per our subcategories, we followed the procedures defined by the experiments selected through the inquiry-based curriculum that was used (Tables 16.1 and 16.2). Using these as our starting points and following the data which emerged through our pilot study, we added new subcategories or refined categories according to the transcribed data collected. The methods used in analyzing students' group work in each experiment tried to capture a viewpoint of both students' work in each group as well as the interactions which emerged through students'-instructors' conversations.

During the completion of our coding scheme, we first acknowledged that dialogues among students contained, apart from questions and answers regarding both context and experimental procedures, statements regarding the context of the studies (scientifically accepted or not) as well as neutral comments regarding the conceptual context of each experiment. Thus, we expanded the category of students' dialogues with the three codes discovered. Finally, the coding scheme involved six categories, with their subcategories presented. Table 16.3 provides an example of the descriptions of one of the six codes, namely, the inquiry cycle category, and short examples of the coded conversation. After finalizing the coding scheme, all coding was carried out by the two authors (Cohen's Kappa 0.88). Differences in the assigned codes were resolved through discussion.

For the purposes of this study after coding students' actions (see Table 16.1), we constructed timeline graphs, following the approach of Schoenfeld (1989). The *x*-axis of the graph displayed time, and the *y*-axis displayed students' actions. Each action corresponded to a different category of the inquiry cycle (e.g., prediction, observation, etc.). The use of these graphs was to identify any possible interrelationships of the codes (students' actions) over time (see Zacharia & de Jong, 2014). Timeline graphs were produced for experiment 4.1 for each group of each condition. The resulting graphs were compared both within and between conditions.

Additionally the analysis of the reflective journals was based on the memos/profile of each group, which was generated during the interventions from the instructors (Patton, 2002). Specifically, the journals were analyzed in terms of identifying the extent and the manner in which students discussed issues related to the main concepts to be addressed at both experiments. This helped us get a fundamental insight into the areas in which each group consider important in constructing its mental model. Additionally, having developed initial insights about each group foci and difficulties, the analysis of the reflective journals included coding of the issues/

Table 16.2 The experimental procedures/actions coding scheme

Category	Codes
Inquiry cycle	(a) Prediction, (b) experimentation, (c) observations, (d) explanations (evaluation of predictions and observations), (e) conclusions [(i) discussion with instructors at check points, (ii) discussion after the intervention of instructors, (iii) discussion with instructors after students' concluding questions]
Type of activity	(a) Completion of worksheets, (b) use of PM, (c) use of VM, (d) discussion of scientific content or experimental setup, (e) irrelevant comments

Table 16.3 The "inquiry cycle" analysis

Subcategory	Subcategory description	Transcribed data
Prediction	Reference to pre-existing knowledge regarding the experiment to be conducted	"Predict what you would see on the screen if you place a green acetate in front of a red and green color light beam." "we would have seen it green and red, right (the result on the screen)?" (*Student 2*, *group B*, *PM*)
Conversation regarding the experimental set up	Conversation regarding the procedural sequence of conducting the experiment	"Here is the room. Change the radiation angle in order to lighten the screen" (*Student 2*, *group A*, *PMVM*)
Direct observation	Collecting data through senses during experimentation	"It's black. If you place green light through red acetate the result is black. If you place red color, you will observe red, you see, its red." (*Student 3*, *group A*, *PMVM*)
Explanation	Constructing explanations and data analysis, based on pre-existing knowledge and conceptions derived through the analysis	"The secondary colors come from the mixture of primary colors (mixtures in paint). Cyan, magenta and yellow are secondary colors in light" (*Student 1*, *group A*, *PM*)
Student-instructor conversation at checkpoints	Discussing the experimental results in each experiment with instructors at the check points of the curriculum material (see physics by inquiry curriculum, McDermott & The Physics Education Group, 1996)	"Which are the secondary colors that emerge through the mixture of the primary colors of light?" (*Instructor*, *group A*, *PM*)
Student-instructor conversation after an instructor's intervention	Discussing the experimental results or the experimental procedures taking place after an instructor's intervention to the experimental procedure (e.g., in difficulties emerge through experimenting with PM or VM)	"There is a difference in conducting this experiment in relation to that experiment" (*Instructor*, *group A*, *PM*)
Student-instructor conversation due to a student's question	Discussing the experimental results or the experimental procedures taking place after a students' question	"Basically we tried to combine two colors and we accidentally left one colored beam working and we observed black, and we cannot explain this" (*Student 1*, *group A*, *PMVM*)
Irrelevant comments	Irrelevant comments regarding the domain under study	"When we finish class, we must talk regarding the exams." (*Student 3*, *group A*, *PM*)

problems raised during experimentation regarding either the experimental setup or the scientific context at hand.

Results

The data analysis revealed that PM and the blended combination of PM and VM elicited different discussions and actions during experimentation. In fact, the analysis showed that student actions appeared to be influenced in specific categories of analysis by the means of experimentation, while in others the curriculum material dominated students' actions and behavior (see Table 16.4).

Inquiry Cycle

The analysis of the category "inquiry cycle" revealed differences among the two conditions in students' actions during both experiments. Specifically, in both experiments analyzed, the blended combination of PMVM was found to have a much higher number of student utterances concerning direct observations during experimentation than PM alone. No differences were found between the two conditions during the analysis in the rest of the subcategories of the "inquiry cycle," in both experiments. The analysis of the reflective journals revealed that PMVM students would combine and compare their direct observations through both means (PM and VM) for the same experiment. Particularly in certain occasions, such as when secondary colors of light were mixed (experiment 4.1), PMVM students felt the need of observing this phenomenon on both VM and PM, despite the fact that the curriculum material instructed them to conduct these observations using only VM. In addition, during their first time of using colored acetates and colored light in experiment 4.1, students who used PM in both conditions confronted difficulties in using the laboratory's equipment according to the curriculum material, which triggered the interventions of the instructors during experimentation (e.g., how to mix green with red light). The PMVM students did not face these problems/issues, which appears to indicate that the presence of VM enabled PMVM students handle these issues on their own.

Who Is Talking

The category of "who is talking" refers both to student-to-student and to instructor-to-student talk and includes all dialogue components (e.g., questions posed, answers or suggestions offered, etc.; see the coding scheme in Table 16.1) regardless of the activity taking place. In terms of who is talking during experimentation, our

Table 16.4 Students' discourse and procedures/actions during PM and PMVM experimentation in experiment 4.1

Discourse and experimental actions	Categories	PM		PMVM	
		Group A	Group B	Group A	Group B
Inquiry cycle	Predictions	4	20	5	52
	Experimentation	52	133	139	128
	Observations	120	74	317	400
	Explanations (evaluation of predictions and observations)	102	90	262	101
	Conclusions—Discussion with instructors at checkpoints	87	200	112	91
	Conclusions—Discussion after the intervention of instructors	51	49	18	79
	Conclusions—Discussion with instructors after students' concluding questions	22	30	39	75
	Irrelevant comments	18	171	19	94
Who is talking	Students	369	641	830	921
	Instructors	80	122	81	99
Type of activity	Completion of worksheets	13	16	39	95
	Use of VM	0	0	182	274
	Use of PM	89	85	186	265
	Discussion of scientific content or experimental setup	335	494	485	292
	Irrelevant comments	17	173	19	94
Dialogue components	Scientifically accepted answers	33	39	76	59
	Scientifically not accepted answers	13	21	35	39
	Questions regarding scientific content	63	77	165	139
	Scientifically accepted statements	39	61	132	150
	Scientifically not accepted statements	24	35	66	75
	Comments about scientific content	51	102	92	82
	Reading instructions	9	13	7	10
	Irrelevant comments	34	182	20	95
	Procedural comments	54	106	103	128
	Questions regarding the experimental procedures	41	32	53	77
	Scientifically accepted answers regarding the experimental procedure	20	15	29	30
	Scientifically not accepted answers regarding the experimental procedure	5	3	2	3
	Comments regarding the experimental procedure	63	81	131	133

(continued)

Table 16.4 (continued)

Discourse and experimental actions	Categories	PM		PMVM	
		Group A	Group B	Group A	Group B
Predictions	Scientifically accepted prediction based on previous experiment	0	0	3	4
	Scientifically not accepted prediction based on previous experiment	0	7	1	4
	Scientifically accepted prediction based on previous knowledge	0	0	0	0
	Scientifically not accepted prediction based on previous knowledge	0	0	0	4
Explanations	Scientifically accepted explanation based on the experiment at task	25	52	79	54
	Scientifically not accepted explanation based on the experiment at task	14	13	36	21
	Scientifically accepted explanation based on previous experiment	3	13	17	8
	Scientifically not accepted explanation based on previous experiment	1	3	10	4
	Scientifically accepted explanation based on previous knowledge	0	0	0	3
	Scientifically not accepted explanation based on previous knowledge	0	0	0	0

analysis revealed different results in the two experiments. Specifically, PMVM students were found to talk comparatively longer than their PM counterparts during the experiment 4.1, whereas at the second experiment (4.4), no differences were found. These results are deeply connected with the results of the "inquiry cycle" category. Since PMVM students conducted more rounds of experiments and made more direct observations, especially during the experiment 4.1, they spent more time discussing their findings between them and with the instructors. The reflective journals revealed that during experiment 4.1, students were involved in discussions of contrasting their observations taken between PM and VM, something that was not required by the curriculum material. Having done that, PMVM students felt no need of following the same procedure in the experiment 4.4, at least not at the same extent, which led to no differences between the two conditions.

Dialogue Components

Students in PMVM condition elicited nearly a double number of questions concerning the scientific content, in comparison with their counterparts in the PM condition (165 and 139 questions made by the PMVM groups A and B, respectively; 63 and 77 questions made by the PM groups A and B, respectively). Similarly, PMVM students elicited a double number of answers regarding the scientific concepts at task (76 and 59 answers stated by the PMVM groups A and B, respectively; 33 and 39 answers stated by the PM groups A and B, respectively). Additionally, the PMVM students stated approximately three times more scientifically accepted statements than the students in PM condition during experiment 4.1. No such differences emerged between the two conditions during experiment 4.4.

The number of questions regarding the experimental setup of the experiment, as well as the answers given, followed a similar pattern in both experiments, though a slight difference was observed in favor of PMVM students during experiment 4.1 (77 and 53 questions stated by the PMVM groups A and B, respectively; 41 and 32 questions stated by the PM groups A and B, respectively). PMVM students asked more questions on content than students in PM condition during experiment 4.1. They also proceeded in stating more comments when setting up the same experiment. To this end, no differences emerged for experiment 4.4. Moreover, our analysis showed no differences among the two conditions in stating neutral comments on scientific content, in reading instructions from the curriculum material and on irrelevant comments in both experiments. The analysis of experiment 4.4 presented only one difference between the two conditions, specifically in organizing procedural matters during experimentation. The PMVM condition bended on procedural issues during the experiment of absorption of colored light, presenting a double number of student utterances in comparison with the PM condition. This result emerged due to the preparatory work of the two PMVM groups, in writing down a series of tests and measures they later on followed to construct their explanations of how light travels through color acetates. Again, these results are strongly connected with the experimental procedures followed from the students in each condition.

The fact that PMVM students elicited more questions and answers concerning the scientific content as well as more scientifically accepted statements is connected to the fact that students proceeded in their own initiative in discussing the results emerging from both means of experimentation. Though different parts of each experiment were conducted with PM or VM, students had no problem of engaging in more inquiry cycles (using POE strategy), using observations or experimental procedures conducted or applied in PM and VM conditions interchangeably, and in reaching safe conclusions regarding the results of mixing colored light. The fact that most differences were only derived through the analysis of experiment 4.1 may be related to the fact that many of the issues students had during experimentation were addressed, so they confronted no difficulties in using or in engaging in new experimental procedures with PM or VM during experiment 4.4. For instance, PMVM students had already understood the underlying mechanism of the use of color acetates in color light mixtures before they engage in experiment 4.4. Despite the fact that similar results emerged in this experiment with PM students, it was likely that PMVM students had reach to deep understanding of how colored acetates worked before they reach to the aforementioned experiment. Hence PMVM students, having no important issues to address in terms of conceptual understanding of the phenomenon studied (use of colored acetates, analysis of colored light and mixing of colored light) dedicated comparatively more time in organizing all their experimental efforts (specifically colored light combinations with the use of all colored filters at hand), before enacting the experimentation procedures. Students in PM condition did not proceed to this level of organizing their work because they felt at some point like involving in sumptuous procedures when other important understanding issues, like for instance, understanding the mechanism of the phenomenon of absorbing colored light through acetates, were still at hand.

Predictions and Explanations

No significant differentiations emerged through the analysis and comparison of students utterances among the two conditions regarding the conduction of predictions in both experiments. According to the curriculum material, both experiments did not require explicit predictions before experimenting with physical or virtual materials, so students did not proceed with stating a high number of predictions. In terms of constructing explanations, students in all conditions made a conscious effort on constructing their explanations, mainly from data based on experiments conducted through the curriculum material. No differences emerged through the comparison of the two conditions, regarding students' utterances in constructing their explanations. The results of the experiments conducted through the curriculum material supported the procedure of constructing explanations. Our analysis showed that students were based primarily on the results of experiments conducted as well as on previous results of the curriculum material. To this end, the curriculum material dominated the documentation of students' explanations, regardless of the manipulatives used during experimentation. No differences emerged among the two conditions regarding the number of scientific explanations that could be linked or attributed to the means of experimentation of each condition.

Type of Activity in PM and PMVM

In analyzing the type of activity taking place in both conditions, specific patterns emerged which could be attributed to the means of experimentation in each condition. Despite the fact that our analysis elicited differences among the two experiments in both conditions, similar patterns emerged according to the means of experimentation used in each condition. Specifically in experiment 4.1, PMVM students experimented either on PM or VM for a far more significant amount of time than their counterparts working with PM (see Fig. 16.2). During experiment 4.4, students in PMVM used for a great amount of time the virtual laboratory Optilab during experimentation. In both experiments, the use of PM was the least, in terms of time and students' utterances. The time allocated from each condition in the actual use of the means of experimentation (PM or PMVM) is also documented from the results on the "inquiry cycle" category, in which timeline graphs show that

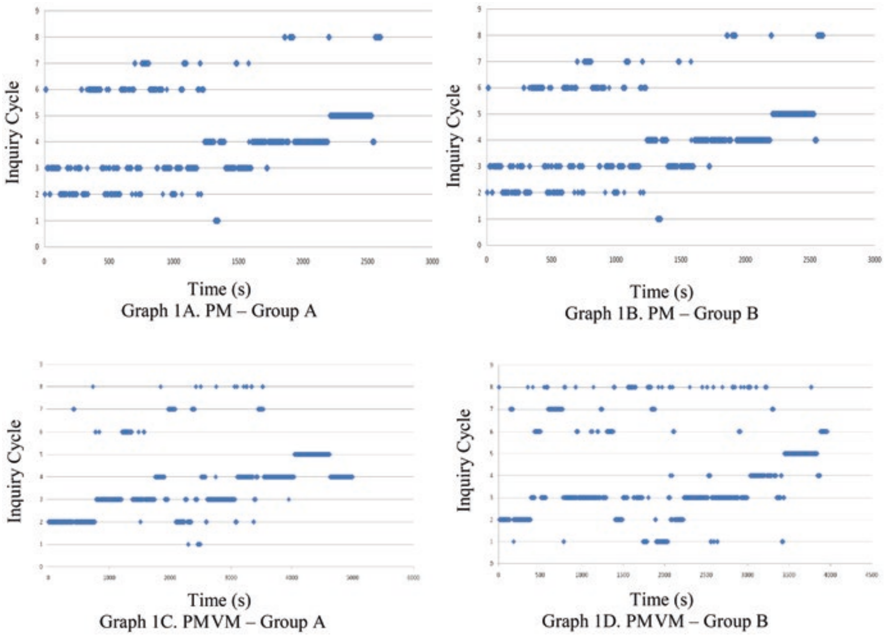

Fig. 16.2 Time graphs of student utterances in the category "inquiry cycle." Graph 1A presents students' actions over time in PM condition (group A of the PM condition) using PM to conduct experiment 4.1 (from part C of the curriculum). Graph 1B presents students' actions over time in PM condition (group B of the PM condition) using PM to conduct experiment 4.1 (from part C of the curriculum). Graph 1C presents students' actions over time in PMVM condition (group A of the PMVM condition) using PMVM to conduct experiment 4.1 (from part C of the curriculum). Graph 1D presents students' actions over time in PMVM condition (group B of the PMVM condition) using PMVM to conduct experiment 4.1 (from part C of the curriculum). The inquiry cycle is analyzed to (1) prediction; (2) experimentation; (3) observations; (4) explanations (evaluation of predictions and observations); (5) conclusions, discussion with instructors at check points; (6) conclusions, discussion after the intervention of instructors; (7) conclusions, discussion with instructors after students' concluding questions; and (8) irrelevant comments

PMVM students during their observations used longer the means of experimentation at hand than their PM counterparts did (see Fig. 16.2).

A slight difference also occurred in completing the worksheets of the curriculum material, among the two conditions in both experiments. Our analysis showed that PMVM students worked on their worksheets longer than PM students did. This result is in line with the increased utterances on discussions that the PMVM condition elicited during experiment 4.4. Specifically, students working with VM at the PMVM condition proceeded in writing down all the combinations of different colors of light travelling through different colored acetates in their worksheets before going forward on conducting the actual experiment. This action was not followed by the PM students, in any of the two groups.

Overall, the PMVM students made a significantly higher number of observations than their counterparts in both experiments, as their utterances prevail in numbers.

Students in the blended combination condition used their means of experimentation more frequently in comparison with the PM condition. This result was mainly profound in the experiment 4.1. Finally, the PMVM students organized the process of mixing colored light in a different manner than PM students, namely, writing and numbering down all their prospective efforts (e.g., colored light mixings).

Discussion and Implications

In the current study, we investigated how students' actions and procedures followed and compared between two conditions, namely, the use of PM alone or the use of a blended combination of PM and VM. In the Olympiou and Zacharia (2012) study, it was found that the blended combination of PM and VM was more conducive to students' conceptual understanding than the use of PM alone. Given this finding, we decided to examine the reasons for causing this differentiation. In so doing, we focused on students' actions, as identified through their actions on videos and as portrayed through their conversations. The idea was to examine whether any variations in actions during experimentation result in different learning outcomes/performance. The findings of this study were particularly revealing in this respect. Specifically, we found in both experiments that the use of PMVM leads students to more rounds of experiments which results in more direct observations (i.e., better data collection/evidence). Students in the blended condition had the chance of using both PM and VM interchangeably, so there were instances in which students after having the opportunity of the real/concrete experience with mixing colored light or light absorption, they could turn to the VM experience to observe in a "more accurate" (i.e., less messier) and quicker manner all different kinds of colored light combinations or absorptions. Such instances occurred more frequently when PM did not offer to students' clear observable outcomes (i.e., due to other light contamination). In the case of PM alone, students spent much time on discussing about these issues, rather than extending their data pool, as it was the case with the PMVM condition. In addition, the fact that in the PMVM condition the data collected were triangulated from two different means of experimentation provided the PMVM students more confidence in terms of the credibility of their findings, which allowed them to have more productive discussions and thus deepen their understanding. On the other hand, the PM alone students were lacking such confidence. As a result, PM students had to struggle to clarify and consent on what color they were observing on the screen.

Students in both conditions expressed similar numbers of prediction and explanation statements. This could be explained by the fact that the curriculum requested from the students to state predictions or explanations at particular parts of the experiments. In other words, given the context of this study, we could not make a claim on whether the means of experimentation affect the number of predictions or explanations stated by the students. Moreover, we cannot make any arguments about their quality (e.g., the scientific accuracy and the degree of deepening of explanations). For the latter, further analysis is needed.

Amazingly, the PMVM students dedicated a significant amount of time in using the means of experimentation for conducting more rounds of the same experiment (with slight alterations every time, e.g., first mix green and blue, then blue and red, etc.) and thus making more observations, instead of proceeding with the rest of the curriculum materials. At the same time, they took the time to fully complete their worksheets by writing down all the possible mixtures of colored light before starting experimentation, hence, not leaving room for missing any combinations. PM students did not follow the same process (they were completing them during experimentation and not following a specific pattern as their counterparts did).

These findings shed light on how VM affordances could be used, along with PM, to maximize instructional or experimental time for deeper conceptual understanding of the domain under study (see Olympiou & Zacharia, 2012) or in organizing better students' group work when experimenting. Moreover, this study showed that the use of different means of experimentation, namely, PM alone or a blended combination of PM and VM, influences aspects of the experimental procedures/actions in a different way. This implies that the selection of the means of experimentation is crucial if we want certain procedures/actions to be in place during experimentation (e.g., going through more observations hence, more inquiry cycles). The same holds true if we aim to establish among students and instructors productive conversations. In this study, it was found that the blended combination was the mode of experimentation that better offered students these opportunities, with VM, along with its affordances, to be the means of experimentation that contributed the most toward this end.

The literature suggests that there is no question whether blended combinations of PM and VM should be used in physics experimentation (e.g., Zacharia & Michael, 2016). The optimization of PM and VM blends may be achieved through efforts similar to the one of this study. By knowing how VM and PM interact with students' actions, we could work toward a better defined and accurate framework on blending PM and VM for optimizing students' learning.

The findings of this study have implications both for researchers and for educators. For researchers, the study points toward a specific research path that needs to be followed in order to unpack the procedures/actions that take place during PM and/or VM experimentation and to better understand their relationship with learning. This study also highlights the essence of selecting means of experimentation. The fact that the means of experimentation might define the number of observations conducted or the level of organizing students' actions in a laboratory could be a fundamental parameter in achieving the prospective learning outcomes in previous efforts of blended combinations of PM and VM. It is of great importance for educators to be informed when to use PM and VM, since it appears that different means of experimentation evoke different procedures/actions during experimentation.

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Chapter 17
The Impact of Virtual Laboratory Environments in Teaching-by-Inquiry Electric Circuits in Greek Secondary Education: The ElectroLab Project

Athanasios Taramopoulos and Dimitrios Psillos

Introduction

Virtual Laboratory Environments

The last two decades have seen the development of a large group of educational software in physical sciences, the virtual laboratory environments that simulate in a visual and functional manner the laboratories of physical sciences on a computer screen. This has been possible by exploiting modern multimedia technology, interactive interfaces, and direct and realistic handling of objects and parameters (Psillos et al., 2008). The ability of this software to be used in teaching in an analogous way to real school laboratories has initiated a discussion of redefinition of the role of the experiment in scientific teaching (Hofstein & Lunetta, 2004). A significant number of studies have shown that virtual laboratories as educational environments are not inferior to their real counterparts (Rutten, van Joolingen, & van der Veen, 2012). But virtual laboratory environments differ from one another in the affordances offered to the users (e.g., graphical presentations, microscopic phenomena views, degree of interaction with the simulated phenomena, etc.), in the fidelity of the represented physical world (from realistic to purely schematic representation, as shown in Fig. 17.1), the physical phenomena simulated, and the accuracy of the simulation. It has been found that these characteristics of the virtual laboratories may have a significant impact on the teaching outcome (Olympiou, Zacharia, & de Jong, 2012; Rutten et al., 2012).

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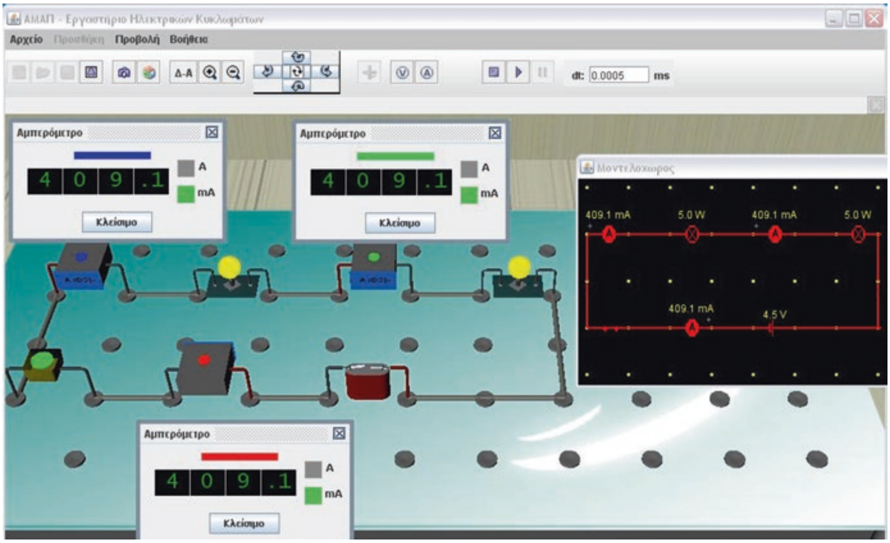


Fig. 17.1 The virtual laboratory of electric circuits of OLLE allows for the use of virtual instruments with different representation concreteness

Evaggelou and Kotsis remark in their review (2009) that such studies focus mainly on university students and only a few were tried out with elementary or secondary education students. Regarding secondary education, no study deals with the field of electric circuits, which is particularly suited to a comparison between virtual and real laboratory environments.

Teaching with Multiple Representations

One of the key features of virtual laboratory environments is the capacity to use multiple representations to present the simulated phenomena. Multimedia and multi-representational learning environments are widely used in classrooms and support a variety of learning activities. However, different types of representations differ in their computational effectiveness (Schnotz & Bannert, 2003), and the representations used in learning environments influence students' construction of scientific understanding and their ability to transfer scientific knowledge to various situations (Scheiter, Gerjets, Huk, Imhof, & Kammerer, 2009). There is evidence that utilizing multi-representational learning environments helps foster students' problem-solving ability, since they are less prone to be confused by the representation in which the problem is manifested (Rosengrant, Etkina, & Van Heuvelen, 2006). However, little is still known about how we learn from different representational formats and how these processes are related to learning outcomes (Kühl, Scheiter, Gerjets, & Gemballa, 2011).

Nevertheless it is generally believed that students may gain from the properties of each representation used and that multi-representational instruction will lead to a deeper understanding of the scientific domain under study. Such a deeper understanding of the domain may also occur when students build abstractions by translating between representations in a multi-representational environment (Ainsworth & van Labeke, 2004). However the issue is not settled yet. Learning with multiple representations presents various difficulties for the students, since for each representation used they have to understand the form of the representation, the relation between the representation and the domain, how to select the most appropriate representation to use when confronted with a problem, and how to construct an appropriate representation (Ainsworth, 2006). Furthermore, different representations require students to correlate different sources of information, which may cause them to display a split-attention effect (Mayer & Moreno, 1998), also producing a heavy cognitive load and leaving few resources available for actual learning (Sweller, van Merrienboer, & Paas, 1998).

Rationale

In the field of DC electric circuits, in particular, which is a field of physical sciences that everyone encounters daily and has been a topic of science education continuously over the last 30 years, it has been found that important and widely spread alternative views exist which are very hard to change (Engelhardt & Beichner, 2004; Psillos, 1997). Consequently, studies with virtual or physical laboratory environments have mainly focused on the students' conceptual difficulties, overlooking other learning objectives, like the ability to transfer knowledge from the teaching environment to the real world for solving everyday problems or student understanding of how to design and implement experiments with electric circuits. Besides, to the best of our knowledge, there exist no studies comparing the effectiveness of teaching DC electric circuits in secondary education using investigative activities employing virtual laboratories that contain object representations of various levels of concreteness. Such studies might contribute significantly to our understanding of the differences reported in students' problem-solving abilities and shed light on the difficulties they encounter in translating a circuit from one form to another. Circuit transformation and knowledge transfer from one representation to another are essential ingredients for problem solving and experimentation, as circuit schematics are usually presented or drawn in the design phase whereas real or virtual circuits are realized in the implementation phase.

In this framework, the ElectroLab project was designed and is being implemented by researchers and experienced teachers. The project is a research and development program aiming at developing a suitable educational virtual laboratory environment and multiply assessing the role that virtual laboratory environments may play when incorporated in teaching-by-inquiry DC electric circuits (Psillos et al., 2008). The program is implemented through field research studies in students of secondary education in Greece, comparing various aspects of teaching effectiveness when it is performed with virtual laboratory environments of various features.

In the ElectroLab project, a comparison of the impact of virtual laboratories is made when used in teaching by inquiry DC electric circuits with regard to (1) the conceptual evolution of students, (2) the students' ability to transfer knowledge to other representations by transforming an electric circuit from one representation to another (real, virtual, schematic), and (3) the students' ability to design and carry out experiments with simple electric circuits. In this chapter results of this program are reviewed along the three aforementioned axes and are compared to similar international research studies.

The OLLE Virtual Laboratory Environment

Most of the ElectroLab studies used the virtual laboratory of electric circuits of the Open Learning Laboratory Environment (OLLE). OLLE is an open three-dimensional virtual laboratory in the fields of optics and electricity with navigation and rotation capabilities (Bisdikian, Psillos, Hatzikraniotis, & Barbas, 2006; Psillos et al., 2008; Taramopoulos & Psillos, 2017; Taramopoulos, Psillos, & Hatzikraniotis, 2011b). Users may construct the setup of their choice, adjust the parameters of their instruments, and explore their behavior while the virtual instruments are fully and continuously functional. It was developed in the general framework of our research and development program, and it is widely used in Greece and other Greek-speaking countries either in optics or in electricity (Olympiou et al., 2012; Taramopoulos & Psillos, 2017).

OLLE also provides its users with an additional tool in the virtual laboratory, which bridges the gap between the realistic virtual laboratory world and the governing underlying physics laws: the model space tool (Fig. 17.1), which depicts a two-dimensional symbolic representation of the real laboratory setup. In optics the model space tool depicts in real time the light rays and models of the lenses and the other instruments used; in static electricity and magnetism, the model space tool shows synchronously the symbols of the electric charges and magnets and the accompanying electric and magnetic fields of the user's virtual setup; and in the electric circuits laboratory, it displays in real time the schematics of the circuit constructed by the user. The model space is more realistic and concrete than abstract general laws, but also more abstract and general than a depiction of the physical phenomena. The model space is thus positioned between physical phenomena and physical laws and may be considered to be a model of the laboratory setup. This duality of representation designed into OLLE is hoped to be capable of effectively scaffolding learners to acquire a deeper level of understanding and overcome higher-level difficulties in the domain of electricity and optics.

OLLE allows its user to store the experimental setup in the form of a fully functional Java applet. In practical terms, this means that from each experimental setup, a new simulation can be exported, in the form of an applet, which can be executed independently of OLLE. These simulations are similar in appearance to the two-dimensional model space tool, with the addition of the freedom of handling existing in the three-dimensional virtual lab (ability to move an object and alter its properties). These virtual labs with abstract representations of their objects are therefore fully functional two-dimensional symbolic multi-parametric representations of the virtual laboratory, highly consistent with the theory.

OLLE thus provides the teacher with three distinct possibilities for use: a realistic three-dimensional virtual laboratory, a fully functional abstract two-dimensional model (applet), and a virtual laboratory where the concrete and abstract representations coexist side by side and are dynamically linked. It is up to the teacher to use any of these possibilities, depending on the desired learning outcomes in each case. This unique design feature makes OLLE especially suitable for our program.

Characteristics of the Teaching Interventions

Involving students in laboratory activities in science courses is alleged to contribute not only to the construction of content knowledge but also to understanding aspects of scientific inquiry. Physics teaching is compulsory in Greek secondary education and so is the curriculum. In our studies, an innovative guided-inquiry approach was adopted with some variations depending on the level and specific case objectives. The main features are that students, guided by the teacher and suitably structured worksheets, investigate the behavior of electric circuits and the laws they adhere to. All materials were adapted to the junior or senior high school curriculum, depending on the age of the students. The various interventions were based on coherent teaching/learning sequences consisting of structured activity worksheets based on a laboratory variation of the predict-observe-explain strategy (White & Gunstone, 1992) with activities concerning setting of problems and questions, making predictions, designing and performing suitable experiments, discussions, interpretation of results, drawing, and sharing conclusions. Students were guided through a sequence of phases to explore a problem (e.g., construct an appropriate circuit, and measure the intensity of the current with different bulbs), search for the answer, design experiments, take data, cooperate, discuss, evaluate their predictions, and present their findings. Guidance during teaching varied. It was lessened as the teaching sequence progressed and students became more familiar with scientific experimental procedures. Teaching can thus be classified as starting with structured inquiry in the first units and gradually shifting and ending in guided inquiry in the last units (Zion & Shedletzky, 2006).

Work in class took place in groups of two, whereas the activity worksheets were separately completed by each student. Most of the worksheets of the teaching sequences were of hourly duration, and there were a lot of activities in the worksheets where students discuss in class and take notes. This was deemed necessary to stimulate students' exchange of views and ideas, help student reflect on their views, and restructure their knowledge. At the end of each worksheet, students were assigned homework comprised of meta-cognitive questions. Homework was done individually.

Impact on Students' Conceptual Evolution

In the area of DC electric circuits, research has shown that students carry intuitive conceptions acquired from their everyday experience, which are usually considerably different from the scientifically accepted views and are resistant to change (Engelhardt & Beichner, 2004; McDermott & Shaffer, 1992; Psillos, 1997). Unlike a physical laboratory, in a virtual one the circuit elements do not have a fixed representation and may be presented with a representation fidelity anywhere between highly realistic (concrete representation) to purely schematic (abstract representation), which may influence learning outcomes. It has been found that traditional teaching using abstract electric circuit representations leads to an increased ability to solve simple problems or problems similar to the ones dealt with during teaching, compared to teaching using realistic representations of circuit elements (Moreno, Reisslein, & Ozogul, 2009). It is suggested that the absence of excessive information in the representation helps students focus on the important aspects of the phenomena under study (Reisslein, Moreno, & Ozogul, 2010). The same researchers have also found that the combination of using abstract circuit schematics with a realistic everyday description of a problem leads to increased problem-solving ability on the part of students, compared to purely abstract or purely realistic approaches. Increased problem-solving ability in electric circuits is also reported when students are taught using simultaneously abstract and realistic circuit representations, which effectively supports bridging and blending newly acquired and pre-existing knowledge (Moreno, Ozogul, & Reisslein, 2011).

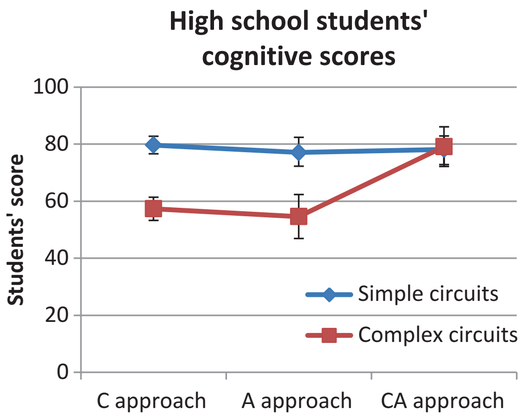
On the other hand, studies in electric circuits and other fields which focus on shifting the representation used during teaching from concrete representations to abstract ones or vice versa report various results. Some researchers suggest that student performance is improved by shifting from concrete to abstract representations (Goldstone & Son, 2005; McNeil & Fyfe, 2012), while others that the shift of representations used during teaching should be from abstract to concrete (Johnson, Reisslein, & Reisslein, 2013). Despite this disagreement, all these results provide some evidence that utilizing multi-representational learning environments may foster students' problem-solving ability or increase their understanding of scientific content. Such a result may be attributed to students being less prone to be confused by the representation in which a problem is displayed, that students gain from the properties of each representation used, and that multi-representational instruction may lead to the construction of a higher-quality mental model and a deeper understanding of the domain under study (de Jong et al., 1998; Seufert, 2003).

However, the above studies were not conducted with a teaching-by-inquiry intervention utilizing open virtual laboratory environments but used either static images or interactive multimedia software with embedded computer-based instruction and drills. Therefore the students did not have the ability to interactively use multiple representations and freely switch between representations at any time instead of representation shifting midway through the teaching intervention. Such an inquiry-based teaching study with virtual laboratory environments was carried out by Jaakkola and Veermans (2015), who conducted their research in primary school. These researchers concluded that pupils benefit more from constantly using a certain representation instead of using multiple representations. They also concluded that the effects of concrete and abstract representations in science education are notably different in elementary school as compared to college contexts, where studies indicate that students benefit more from using multiple representations during teaching instead of being restricted to a single representation (Olympiou et al., 2012).

The impact of virtual laboratories on the students' conceptual evolution in comparison with the impact of hands-on school laboratories when both environments are similarly used in teaching-by-inquiry electric circuits in students of the third grade of junior high school in Greece was studied by Taramopoulos et al. (2011b). The results of this study indicate that the use of virtual or real laboratories does not seem to affect the conceptual evolution of students in electric circuits, since in both cases similar improvements are observed, in agreement with similar international studies (Jaakkola, Nurmi, & Lehtinen, 2011; Zacharia & Olympiou, 2011). Whenever there are reports of differences in the conceptual evolution outcomes, these are attributed to additional characteristics of the virtual laboratories. In particular, Finkelstein et al. (2005) report that the affordance of observing moving charges along electric circuit conductors may scaffold the understanding of related phenomena, and teaching with virtual laboratories that offer such affordances may lead to significantly increased conceptual evolution of students compared to teaching using real laboratories, which does not allow students to view microscopic phenomena.

In one study, Taramopoulos et al. (2011b), exploring the impact of the fidelity of the representation of the real world, report that, for junior high school students, the use of virtual laboratory environments with realistic concrete representations leads to similar conceptual improvement to the use of virtual laboratories with schematics of electric circuits. This is in line with international reports that a circuit in the form of a functional schematic representation when utilized in investigative activities may be an effective tool and facilitate the enhancement of students' conceptual evolution (Wieman, Adams, & Perkins, 2008). But when the virtual laboratory environment combines realistically represented instruments with dynamically linked schematics so that any change in one representation is automatically shown in the other, senior high school students who used the dynamically linked representations environment outperform students who used only a single representation when dealing with problems of relatively high complexity, whereas their scores are similar when involved only with relatively simple problems in electric circuits (Taramopoulos & Psillos, 2017). Figure 17.2 shows graphically the students' scores after the teaching intervention in a posttest cognitive test. It is clear that the students of the CA approach, in which realistic and abstract representations dynamically linked to each other were used, outperform the other two groups (C approach which used concrete

Fig. 17.2 Students' posttest scores for cognitive test with simple and complex problems for teaching-by-inquiry electric circuits with concrete objects (C approach), abstract objects (A approach), and dynamically linked concrete and abstract objects (CA approach)



representations and A group which used abstract representations) when the students face complex problems in electric circuits (red line) but have similar scores to the other two groups when confronted with simple problems (blue line). In fact, students in the CA approach seem to have similar posttest scores for both simple and complex problems, and thus their scores seem to be unaffected by the complexity of the problem. This might indicate that these students have reached a deeper understanding of the subject than the other two groups, so that problems which seem complex to the students of the C or the A approach are easier to comprehend and thus are simple to them.

These results are in line with international research studies in electric circuits in university students according to which different representations may lead to different cognitive results in electric circuits (Moreno et al., 2009) and in other fields of physical sciences (Olympiou et al., 2012). Taking into account all studies, it is suggested that in electric circuits it may be advantageous for a virtual laboratory environment to use constantly only one particular representation when utilized in elementary education (Jaakkola & Veermans, 2015) and dynamically linked realistic and schematic representations when utilized in secondary education (Taramopoulos & Psillos, 2017) or with older students (Olympiou et al., 2012), as at these ages students are more accustomed to using scientific models, and the use of dynamically linked multiple representations may help them build bridges between the models and real objects and detach from a specific representation (Goldstone & Son, 2005; Taramopoulos, 2012).

Impact on Transforming Electric Circuits

Ainsworth (2006) suggests that if multiple representations aim at constraining interpretation or constructing deeper understanding, then translating across these representations should be either automated or scaffolded. In electric circuits a student may be required to first study the circuit's schematics, analyze the circuit's behavior, and then construct it in a virtual or real environment. A student may therefore be frequently required to translate between forms and representations of circuits, which has been found to pose difficulties (Kozma, 2003). However, students often fail to comprehend the relation between two forms or representations, and this may even inhibit learning (Ainsworth, Bibby, & Wood, 2002). In an attempt to better support learning, many learning environments, such as OLLE, have incorporated automatic translation, in which the effects of a student's actions on one form are synchronously shown on another (dynamically linked representations). This is hoped to lessen the burden of performing representation translations on the students, reducing their cognitive load (Scaife & Rogers, 1996), and at the same time support bridging between the representations (Kozma, Russell, Jones, Marx, & Davis, 1996). On the other hand, such an automation may leave students as passive attendees and prevent them from constructing the required understanding (Ainsworth, 1999). To avoid this, the students need to be explicitly guided to study the relationships between the various representations as they unfold before them via properly structured activities and worksheets. Such studies of the ability to transform circuits from one form to another when high school students are actively involved in investigative activities in open virtual laboratory environments have not been performed internationally (Rutten et al., 2012).

Studying the ability of junior high school students to transform a given circuit from one form to another (real, realistic virtual, or schematic), Taramopoulos and Psillos report that the results depend on the complexity of the circuit: for simple circuits the students transform the circuit successfully regardless of the features of the virtual laboratory they used during teaching, but for more complex circuits, the students who used virtual laboratories with dynamically linked realistic and schematic representations during teaching seem to outperform the rest (Taramopoulos, 2012; Taramopoulos & Psillos, 2014). The results of these studies with groups of students who used concrete virtual objects (C approach) and students who used dynamically linked concrete and abstract virtual objects (CA approach) show that the students of both groups seem to be able to transform simple circuits excellently regardless of the direction of transformation (concrete to abstract or vice versa), but all students seem to be less effective in transforming complex circuits, with students of the CA approach outperforming the students of the C approach.

Impact on Experiment Design and Implementation

The ability to design experiments is considered to be one of the most important skills linked to laboratory investigations, possibly surpassing in importance even the actual execution of the experiment, as it is related not only to the content under study but to scientific methodology as well (Garratt & Tomlinson, 2001; Johnstone & Al-Shuaili, 2001). In designing experiments students are involved in identifying variables; listing the devices and instruments needed; describing the experimental setup, the phenomena taking place, and the experimental process; taking and analyzing measurements; and evaluating results. Virtual laboratory environments provide a powerful tool for investigative activities, since students can design aspects of an experiment using multimedia facilities, easily manipulate objects, and try out investigations. Recent studies suggest that virtual laboratories provide affordances which can support students' engagement in experimental investigative activities and enhance their understanding of aspects of scientific inquiry (Klahr, Triona, & Williams, 2007; Lefkos, Psillos, & Hatzikraniotis, 2011).

However, the potential of virtual laboratories to support the development of experimental skills in students in electric circuits has not yet been fully explored (Rutten et al., 2012). Besides, it still remains an open issue whether the representation used in the virtual lab utilized during teaching will have an effect on the students' ability to design and perform experiments. Taramopoulos, Psillos, and Hatzikraniotis (2011a) report that most students who have used virtual laboratories during teaching are able to successfully design and implement an experimental process with simple electric circuits after a teaching intervention where experimental design is not taught directly but indirectly through the continuous involvement of students with electric circuit experiments. Students seem to be able to form hypotheses to answer given research questions, to recognize the variables which affect the phenomenon under consideration, to find the instruments which need to be used for their experimental setup, to design the schematics of suitable circuits to explore the problem, to describe the experimental procedure which need to be followed, to construct the circuit of their experiment, and to record the necessary data, analyze them, calculate the final results, and evaluate them. This is performed successfully regardless of the representation used in the virtual lab utilized during teaching, whether this is realistic, schematic, or dynamically linked realistic and schematic (Taramopoulos, 2012).

Conclusions

The results of our ongoing research and development program, the ElectroLab project, show that teaching-by-inquiry electric circuits using virtual laboratory environments seem to be adequately supporting the conceptual evolution of students (Finkelstein et al., 2005; Jaakkola & Veermans, 2015; Taramopoulos & Psillos, 2014, 2017; Taramopoulos et al., 2011b), the development of skills to transform electric circuits from one form to another (Finkelstein et al., 2005; Goldstone & Son, 2005; Taramopoulos, 2012), and the development of experimental design and implementation skills with simple electric circuits (Taramopoulos, 2012; Taramopoulos et al., 2011a). Contributing factors seem to be specific design features of the virtual laboratories such as the existence of real-time synchronous graphical representations or the existence of dynamically linked representations of different levels of concreteness (realistic and abstract). Such affordances may act as scaffolds for students to acquire a deeper understanding of the domain of electric circuits and consequently be able to successfully cope with problems or circuits of higher complexity. Therefore, virtual laboratories offer teachers an environment into which they can design, develop, and implement investigative laboratory activities, making students interact in a natural way with virtual instruments and actively explore physical phenomena, thus acquiring a deeper understanding that may be transferred to other similar conditions while at the same time developing experimental skills.

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Chapter 18
Tracing Students' Actions in Inquiry-Based Simulations

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Introduction

Simulation (in general) is a representation or model of an event, object, or phenomenon (Thompson, Simonson, & Hargrave, 1996). Specifically, in science education, simulations refer to the use of the computer to simulate dynamic systems of objects in a real or imagined world (Akpan & Andre, 1999). De Jong et al. define a simulation broadly as "a program that contains a model of a system or a process" (de Jong & Van Joolingen, 1998). Simulations may be used to show students scientific phenomena that cannot be observed easily in real time, as, for example, to see the evolution in slow motion or to model phenomena that are invisible to the naked eye (Scalise et al., 2011). They are also employed in teaching where computer simulation offers advantages over traditional settings, as, for example, in situations where several repetitions of an experiment are required, each with varied parameters, within limited instructional time (Scalise et al., 2011).

Research has highlighted the potential and benefits of simulations in various educational methods and strategies applied to the learning process (Esquembre, 2003; Muller, 2008). By using simulations, students are able not only to watch a phenomenon but to interact with it, modifying the initial conditions and thus understanding the correlation between the variables (Cano & Esquembre, 2013). Another advantage of the simulations is that students are given a powerful tool to explain and describe what they have learned, either as a way of controlling their knowledge or by explaining to their classmates (Singley & Anderson, 1989). Last but not least, simulations can help students who lack imagination or experience to create a mental frame of what they hear and read (Aleven & Koedinger, 2002). The production of images and motion through simulations can help students create a strong knowledge base and the necessary mental models (Woloshyn, Paivio, & Pressley, 1994).

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Tracking the students' actions when they use a simulation seems to be a recently emerging research trend. Some researchers use a video camera to record the students' actions and observe the added value of using technology tools in education (Quellmalz, Timms, Silberglitt, & Buckley, 2012). Others allow the mouse or sensors to record the movements of the students. The conventional approach to studying user attention on the computer screen has been through tracking eye gaze (Pan et al., 2004). This approach offers a direct measure of users' overt attention or what they are looking at, and it provides detailed data at millisecond resolution. In recent years, focus has turned to whether mouse tracking could offer a scalable alternative to eye tracking for measuring usability, user attention, and search relevance (Navalpakkam & Churchill, 2012). Computer mouse tracking is a relatively recently developed behavioral methodology that can contribute unique insight into a wide variety of psychological phenomena (Hehman, Stolier, & Freeman, 2015). However, the disadvantage of these approaches is that they do not track the user behavior in their natural state at home or work.

In our recent studies, we have developed computer simulations that have the ability to record students' actions and categorized these actions according to the panels of the simulations (Michaloudis & Hatzikraniotis, 2015a, 2015b, 2016). Recording of students' actions (clicks) was done in the background of the running simulation, invisible to the students, who work at home. We have studied students' understanding and students' ability to variable control through inquiry-based simulations (Michaloudis & Hatzikraniotis, 2017a, 2017b). In this paper, we study the students' actions (clicks) in inquiry-based simulations. Students complete worksheets that follow an inquiry continuum while their actions are recorded by the simulations.

Methodology

The Context

The Approach: Inquiry and Inquiry Continuum

Scientific inquiry refers to the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work (NRC, 2000). As posed to NRC, in inquiry-based learning, learners are engaged by scientifically oriented questions, formulate explanations based on evidence, evaluate their explanations in light of alternative explanations, and finally justify their proposed explanation. Therefore, introducing inquiry in various educational processes actually places the learner in the role of the investigator, the owner of the problem. Learners follow methods and practices similar to the scientific ones to construct knowledge (Keselman, 2003). It can therefore be defined as a process of discovering new causal relationships, with the learner making assumptions and testing them by designing and implementing experimental setups and systematic observations (Pedaste, Mäeots, Leijen, & Sarapuu, 2012). Thus, inquiry aiming at engaging learners in investigating physical phenomena as well as in several facets of scientific understanding can be conceived as both a process and a desired outcome. Research in science education suggests that inquiry-based approaches can be effective in facilitating students' conceptual, methodological, epistemological knowledge and skills as well as enhancing their motivation and interest toward science and technology. Students in compulsory education should have the opportunity to get involved in relevant activities and develop the ability to think and act in ways related to scientific inquiry (Abd-El-Khalick et al., 2004).

While inquiry-based teaching can take multiple forms, the approach can be seen as a continuum from teacher-led to student-led processes. At the lowest level of inquiry ("closed inquiry"), the problem to be investigated, the equipment to be used, and the procedure and the answer to the problem are all given to the students by the teacher or by a worksheet (WS). At the highest level of inquiry ("open inquiry"), the students are required to determine all of these for themselves. This continuum also includes from "closed" to "open" inquiry, the intermediate levels, "structured" and "guided" inquiry, emphasizing the active participation of the learner and his responsibility to discover and construct new knowledge (de Jong & van Joolingen, 1998). Blanchard et al. (2010) note that the "degree of inquiry depends on who is responsible for the activity."

Development of inquiry through these levels is not a linear process. Depending on the level of conceptual and experimental domain that students owned, teachers should focus on different levels of experimental procedure and research each time. For the students, the gradual transition from structured inquiry to guided (a more open level of inquiry), consequently to greater student autonomy, demands guidance from the teacher, so the teacher should scaffold experiences—from highly structured to more open—by varying the amount of guidance, enabling students to come up with self-conceived conclusions (Eick, Meadows, & Balkcom, 2005; Lehtinen & Viiri, 2017). Structuring can vary depending on the classroom context and objectives of teaching.

The "Vehicle": Simulations

Computer simulations are already proven to be of great significance in teaching, mainly in natural sciences (Hertel & Millis, 2002). By adding simulations in pedagogical approaches, such as inquiry-based learning, students are engaged in activities that promote not only conceptual skills but also procedural ones, like scientific process skills and data analysis (Garrison & Kanuka, 2004). Simulations can be used as pre-class, in-class, or after-class activities (Bernstein, Scheerhorn, & Ritter, 2010; Mackinnon & Brett, 2010; Michaloudis & Hatzikraniotis, 2017a; Novak, Patterson, Gavrin, & Christian, 1999).

Our series of simulations were created with the program Easy Java and JavaScript Simulations (EjsS), and they deal with the phenomenon of horizontal throw. EjsS is a free object-oriented authoring tool written in Java that helps nonprogrammers create interactive simulations in Java or JavaScript, mainly for teaching or learning purposes (Esquembre, 2003). In the general case of horizontal throw, where air drag is taken into account, the equation of motion for the projectile is given by

$$m\frac{d\vec{v}}{dt} = m\vec{g} - c\vec{v} \tag{18.1}$$

where m is the projectile mass, $\vec{v} = (v_x, v_z)$ is the velocity vector, $\vec{g} = (0, -g)$ is the acceleration due to gravity, and c a is positive constant for the air drag. Equation 18.1 is integrated numerically by the EjsS built-in RungeKutta-4 algorithm. Simulation results were cross-checked against Interactive Physics® software.

Figure 18.1 depicts a typical layout for the simulations. The main window is divided into five panels, the control panel (settings), the handling panel, the action panel (phenomenon), the representation panel (plots), and the info panel. The "handling panel" serves to execute the simulation (run/stop and reset buttons) and also advance the simulation by one time step forward or backward. In "action panel" (upright), the phenomenon of horizontal throw takes place. In "representations panel" (downright), the graphic plots are evolving simultaneously with the phenomenon. In "control panel" (left), the user can change the values of the independent variables and also observe the values of the dependent ones (Jones, 1985). Using variable-sharing option of EjsS, a change in the variable slider (control panel) will result in a visual change of the projectile's position (action panel), a change in the graph, and a corresponding change in the info panel. Finally the "info panel" provides numerical output for the various variables, like the launch height and velocity, the projectile range and energy, etc.

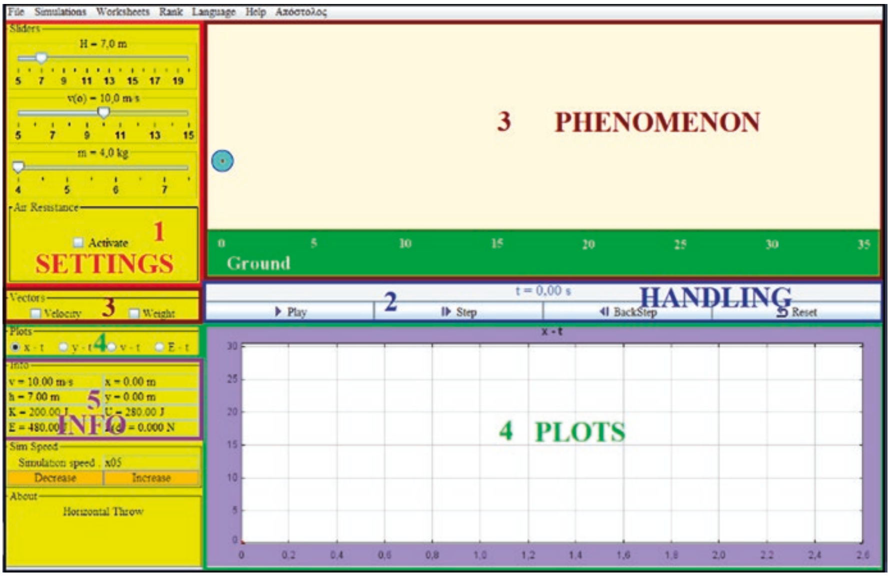


Fig. 18.1 Simulation layout

In the background, the simulation records all the clicks and creates a log file, which is sent to a server. Recording of students' actions on simulations is essential to our research, as we need to know how the students handled the simulations in order to solve the problems, what actions (clicks) they used, how many times for each action, and in what order.

Sample and Method

Eleven (11) students in the fifth grade of high school, aged 16–17 years old, participated in our research. Our group was consisted of five female students and six male ones; all attended a tutoring school,[1] in which one of the authors teaches physics. All students were above average in physics, and the phenomenon of horizontal throw was familiar to them. Our research began 2 months later, after students had been introduced to the phenomenon at school, through conventional teaching. Students had a formalistic knowledge about horizontal throw. It has been checked that the laws and equations which govern the phenomenon were known and that students were able to apply them in solving typical numerical problems in horizontal throw.

Students were not familiar in working with the simulations, using the inquiry-based approach of natural phenomena or possessing scientific process skills. For this reason, the simulations are created in a way to make it easy for the students to read the value of each variable, dependent or independent (info panel). Simulations offer a different approach of the phenomenon, focusing mainly on procedural skills and scientific strategies of research rather than memorization of formulas and laws. Other studies have shown that simulations help students to acquire such skills faster and easier than conventional methods (Smetana & Bell, 2012).

Eight simulations were developed, each one of them addressing a different problem of horizontal throw. Problems were in increasing complexity, varying from single-variable to multivariable ones. Each simulation was accompanied with a worksheet. The worksheets were given one at a time, two times a week. Students completed them with the help of simulations at home. When they delivered them, a discussion followed, where most students expressed questions or impressions about the activity, and the teacher answered their questions. The first activity was presented in the classroom with the teacher helping each student in the whole process (worksheet and simulation).

[1] Tutoring schools is a setting of nonformal education in Greece, which tends to focus on building concrete skills and helping students with what they immediately need to keep up with schoolwork.

The Series of Simulations

The series of simulations consist of eight different simulations, all about the phenomenon of horizontal throw. Our simulations include three independent variables: launch speed, height, and projectile's mass. These variables (or parameters) can be changed through sliders from control panel and can take predefined stepwise values. There is one extra variable, air resistance, with on/off option, which is activated in the last two simulations. Also, there are three dependent variables: the fall time (final time), the final speed, and the projectile's range. Students can attend the values of these variables directly through an information panel under control panel or click either in the action panel or on a plot in the representation panel. In some simulations, there are additional objects (wall, target) for the needs of each activity, and in some of them, certain variables or elements are deactivated (Fig. 18.2).

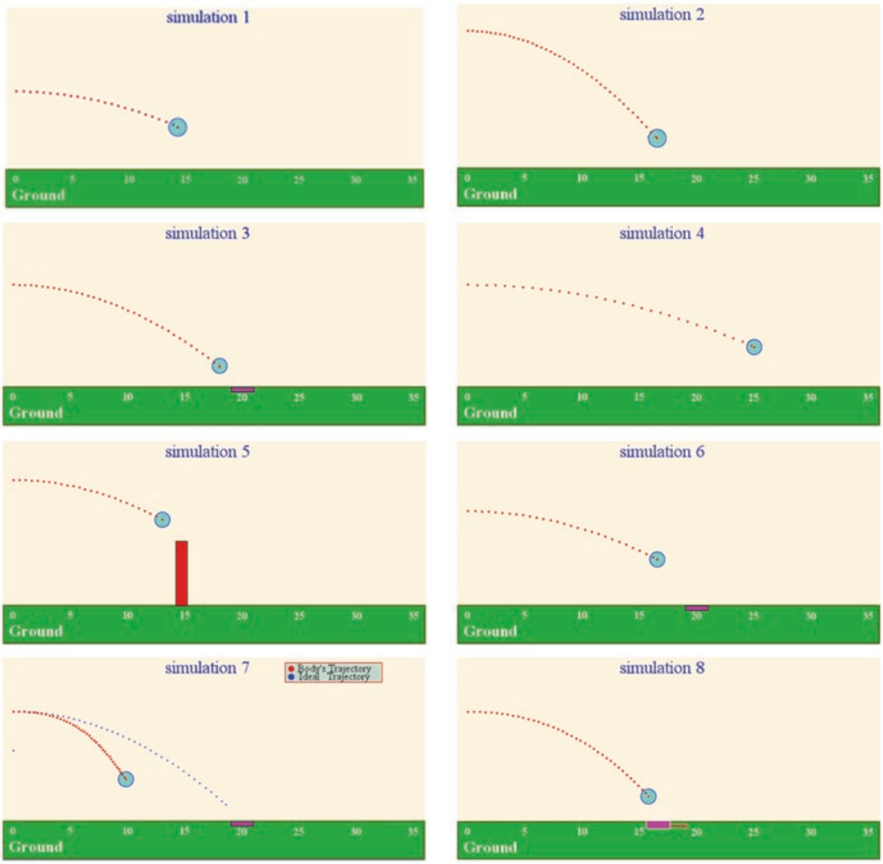


Fig. 18.2 Series of simulations on horizontal throw

In all simulations, there is the option to enable/disable speed and height vectors in phenomenon panel. Also, the trajectory of the throw is visible (red dots). There are four graphic plots available: *x*-position versus time (*x*–*t*), *y*-position versus time (*y*–*t*), speed versus time (*v*–*t*), and energy versus time (*E*–*t*).

Three of the simulations (#1, 2, and 4) were designed as explorative and the remaining five as problem-like. Simulations 1 and 2 were single-variable explorations, for the launch speed (four values available) and for the launch height (seven values available), respectively. In simulation 4, both the launch speed and the launch height were unlocked.

Simulation 3 is a single-variable problem, aiming to land the projectile on a static ground target, by changing the launch speed (seven values), whereas the launch height is fixed. Simulation 5 is a two-variable problem, aiming to overpass a static wall by changing the launch speed (four values) and launch height (three values). Simulations 6, 7, and 8 are three-variable problems; launch speed (three values), launch height (four values), and projectile's mass (four values). In simulation 6, there is a static ground target; simulation 7 is the same problem with the air resistance activated. In simulation 8, the ground target is moving with a constant (unknown) speed, again with air resistance activated.

Worksheets

Trying to bridge laboratory work and the opportunities for different types of learning outcomes, and therefore the way an inquiry approach is partially or fully approached, criteria can be used to classify activities into categories. The degree of openness of activities that compose an inquiry-based process can be assessed in terms of whether the teacher or student decides the problem to be investigated, the variables to take account of, the procedure to follow, the observations and measurements to be done, and the conclusions to be drawn (Mills, 2006).

The worksheets (WS) that accompany the activities, which are carried out using simulations as a vehicle, have an inquiry continuum structure, consisting of three levels. Simulations were set in terms of parameters (or variables) and values per parameter. In level A, there is one-parameter problem; in level B, there are two-parameter problems; and in level C, there are three-parameter problems. Apart from the complexity of the problem (1–2–3 parameters), the amount of guidance provided is varied in the three levels. Two elements of guidance, namely, the "method" and the "solution," define the three levels of inquiry. Table 18.1 summarizes the eight WS from the view of the level of inquiry and the variables of the simulation.

Level A worksheets are similar to what Bell, Smetana, and Binns (2005) describe as "closed inquiry." Worksheets 1 and 2 confirm the (known) relation of the range of throw to the launch speed (WS-1) and to the launch height (WS-2). The method for finding the solution is given, and students are prompted to fill in a table with predetermined values (four for WS-1 and WS-2). WS-3 is a computer variation to a typical numerical problem: "set the launch height (7 values available) so that the projectile lands on a ground target."

Table 18.1 Worksheets on horizontal throw

WS	1	2	3	4	5	6	7	8
Title	Explore v_0	Explore h	Problem: Land on static target	Explore v_0 and h	Problem: Over the wall	Problem: Land on static target w/out air drag	Problem: Land on static target with air drag	Problem: Land on moving target with air drag
Inquiry level	A			B		C		
Method	WS	WS	WS	WS	WS	S	S	S
Solution	WS	WS	WS	S	S	S	S	S
Number of ind. variables	1	1	1	2	2	3	3	3
Launch speed	√			√	√	√	√	√
Launch height		√	√	√	√	√	√	√
Body mass						√	√	√
Air drag	Off	Off	Off	Off	Off	Off	On	On

WS described in the worksheet; *S* student has the control

Level B WS are two-parameter and are designed in a way similar to the "structured level of inquiry." The method of finding the solution is given; however, the solution to the two-parameter problem is worked out by the students. In WS-4, students are asked to adjust the initial height (3 values available) and the initial speed (4 available values, a total of 12 combinations) to explore the relation to the final velocity. WS-5 asks students to make the projectile overcome an obstacle (immovable wall). Like in level A WS, a predetermined table was given to help students to organize their observations. The difference in tables between WS in levels A and B is that in level A WS, the values and the change sequence of the independent variable are given while in level B WS are not.

Level C WS are three-parameter and are designed in a way similar to the "guided level of inquiry"; students are expected to develop a method for finding the solution. WS-6 asks students to land the projectile on a static target, and WS-7 asks students to do the same thing in the case of air resistance present. The last one, WS-8, asks students to land the projectile on a moving target frame (which moves with constant but unknown velocity) to the ground, again with air resistance. In these WS though students are prompted to perform structured observations, as they have learned in the previous WS, no table was given to scaffold structured observations, but students were asked to report their strategy.

Worksheets deal with inquiry-based problems. We urge students to participate, as this is crucial for their learning, and make use of all their knowledge and skills that are relevant to context. In these problems, we try to ask questions that do not have definitive answers which can be answered directly by prior knowledge, but research and interaction with the simulations are needed in order to find the solution. This means that the students need scientific process skills to help them solve the problems.

Recording of Actions

The actions (clicks) that students perform in the simulations are recorded into log files. Log files can potentially give us an insight of the path that each student followed in every worksheet, and combined with the answers given, we can make conclusions about the influence of the level of inquiry in the number and the type of clicks performed.

Students' actions are divided into four types/categories (Fig. 18.1):

- Settings [1]: Clicks that set the value of a variable.
- Handling [2]: Clicks related to the execution of the simulation (play, pause, step, etc.)
- Phenomenon [3]: Clicks on the area of the "action panel" or to activate visual graphics such as vectors.
- Plots [4]: Clicks for plot selection or clicks in graphs to view the coordinates.

Research Questions

Since students already possess a formalistic knowledge about horizontal throw, our research is focused in procedural knowledge. So, we wanted to study if students understand the scientific processes and what kind of strategies they develop to collect data and find solutions.

Studying students' behavior in the simulations and finding if there is any connection between the number and the type of actions (clicks) made, per level of inquiry, was also interesting. To summarize, the research questions were:

- Whether the number of clicks depends on the complexity of the problem (one, two, or more parameter).
- Whether the level of guidance (prompts, heuristics, etc.) provided affects the number of clicks.
- Whether all clicks contribute to the solution of the problem/exploration or there are explorative clicks as well.
- Do students gain scientific process skills through the activity?

Results and Discussion

Our students filled out 88 worksheets. In the log files, 2496 clicks were recorded in total or 227 clicks per student. We counted 1009 clicks on settings, 1136 on handling, 164 on phenomenon, and 187 on plots. There were 469 clicks in level A activities (14.2 per WS), 690 in level B (31.4 per WS), and 1337 clicks in level C of inquiry (40.5 per WS). The total clicks per category for each WS are presented in Fig. 18.3. At a first glance, the number of total clicks per level is increasing, as the complexity of the problem increases, passing from 1 (level A) to 3 (level C) parameters.

All the recorded clicks were analyzed further in an effort to investigate the cause behind each action and its effect in the activity. In other words, we seek which clicks are relevant to the problem and the reason behind the ones that aren't.

Clicks per Category and Level of Inquiry

First, we analyze the number of clicks for each of the four categories, for every single WS, and how relevant is each of those clicks to the problem. Two types of clicks have been identified, namely, the clicks that are relevant to the solution of the problem/exploration and the clicks that have an explorative character, like to explore the range of values of a parameter or the influence of a newly added variable. These clicks may lead to a better understanding of the problem, but not to the solution (Fig. 18.4). Clicks may also underline the strategy for controlling of variables (COV) that students have adopted.

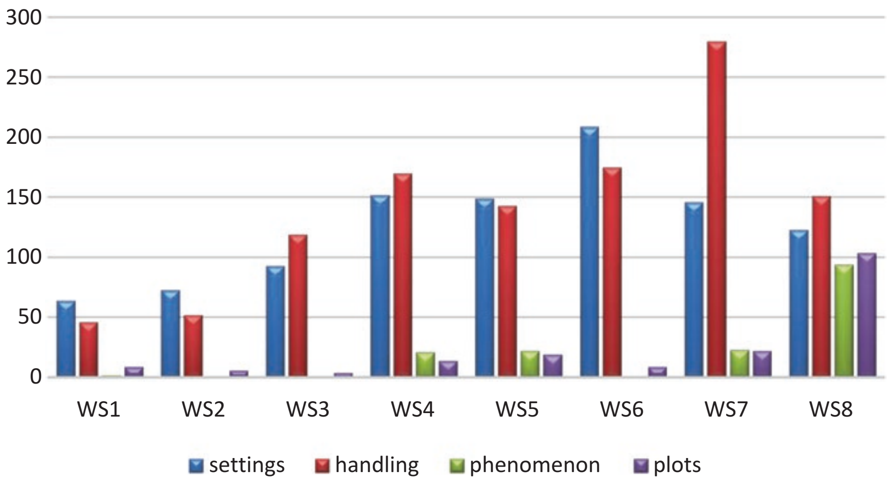
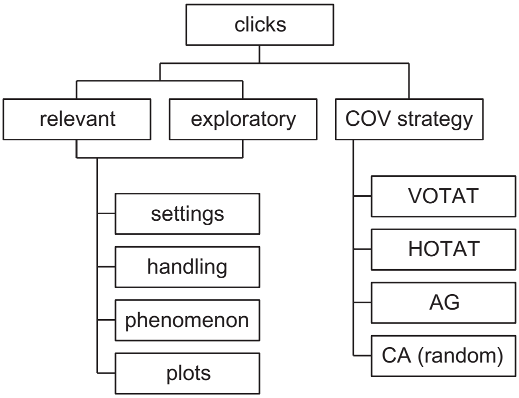


Fig. 18.3 Total number of clicks per category for each worksheet

Fig. 18.4 Types of students' clicks and potential COV strategies, as recorded by the log files



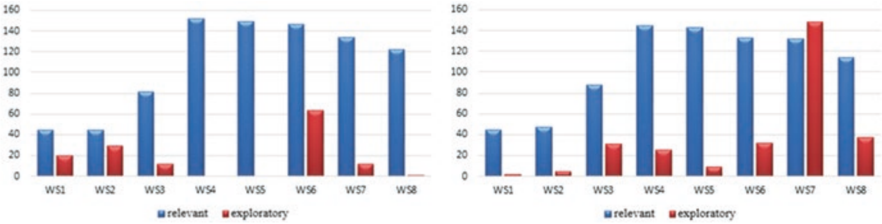


Fig. 18.5 Clicks on settings (left) and on handling (right) per worksheet

Analysis of Clicks on Settings

A closer look at the log files revealed the way that students set the values of the variables, which led us to the need to categorize these actions/clicks (Fig. 18.5). Therefore, an expected setting to a parameter would be in order to take a measurement right after and collect data. So, a click on settings is relevant to the problem if it is followed by a click on play button (handling). This means that the student changed the value of the parameter and clicked on play to see the result of this change. What we find out was that there are clicks on the settings that are not followed by a click on play button.

These unexpected clicks are explorative. In the first three WS, we recorded some clicks in settings before the first time play button was pressed. Before starting to take measurements, students explore the range of each variable, by clicking at all the available values or just to the minimum and the maximum value. Also, when the third variable (body mass) becomes available in the sixth WS, students explore the influence of the new parameter (mass) on the problem.

Examining the results further in relation to the guidance given, we observe that in the first two WS, where the table provided had four incomplete rows, students selected the values to fill in the table. This explains the equal number of "relevant" clicks in both WS. The number of relevant clicks is almost doubled (from 44 to 80) in WS-3. The table that students were prompted to fill in WS-3 had seven incomplete rows. Though it was clearly stated "to find the optimum launch speed (v_0) so that the projectile lands on target," students kept changing values of the launch speed in an attempt to fill out the table even though the projectile had passed the target.

At the two-parameter problems (level B), we see the number of the relevant clicks increasing significantly (from 80 to 150), as expected, since students now have two variables to handle and combining them take more measurements. Interestingly, the number of clicks in both WS is the same, even though WS-4 explores the v_0 and h dependence on s, while WS-5 states "to find the optimum v_0 and h pair as the projectile to pass over the wall." The table given in the WS had the same number of rows, and, similar to the WS-3, students kept changing values of both variables, in an attempt to fill out the table (seven values) even though the projectile had passed over the wall. Therefore, students take as many measurements as the WS either directly prompts or implies them to do.

At level C, the activation of extra parameter (the mass) would logically lead to more clicks. However, in WS-6 (land projectile on a static target), the number of clicks is the same as in the previous (level B) WS. Though in these WS there was no predetermined table to fill, students seem to adopt the same strategy they have used in the previous ones. The last two WS are considered more difficult as air resistance is encountered to the problem. The slightly declining trend in the number of clicks implies that students have refined their strategy, they limit their solution in finding the optimal pair, and they do not longer test all values available for all variables. So, a first conclusion is that the number of the relevant to the problem clicks has to do with the number of the parameters but also with the worksheets' guidance (the given table that students have to complete with the collected data).

Analysis of Clicks on Handling

These actions are interrelated with the actions on settings. Play button is the one we consider relevant to the problem, after changing the value of a parameter. Beyond this, clicks like the reset button, after the end of an observation, is also relevant to the problem. All other clicks, such as pause, step forward, and step backward, are considered as explorative actions.

In general, the relevant to the problem clicks on "handling" follows the same pattern as the clicks on "settings." Moving from level A to level B worksheets, the number of relevant clicks is related to the number of parameters. The slightly declining feature in level C is due to the fact that the students seem to gain experience and lower the number of trials they need to find the solution (Fig. 18.5).

There is a big differentiation at the explorative clicks. In general, the number of these clicks is small per worksheet (from 5 to 30), but in WS-7, the number rises to ~150. A closer look to the log files revealed an extended use of step forward and step backward buttons. In this WS, students study for the first time a horizontal throw with air resistance. In the action panel of the corresponding simulation, the trajectory of the body and the ideal (no air resistance) trajectory are drawn. Students showed a particular interest about the differences of the two trajectories and wanted to study them closely, leading to the use of the "pause," "step forward," and "step backward" buttons.

The conclusions in handling clicks are similar to those in settings, as these two categories are related. Just like in the category of settings, the number of clicks on handling is related to the number of the parameters and also to the guidance provided by the WS. However, there is a significant increase of intentional exploratory clicks, when a new (unknown) phenomenon is encountered.

Analysis of Clicks in Action Panel (Phenomenon)

As noted before, the students were not familiar with the simulations, as this was the first time they faced these kinds of activities. So, simulations were designed in a way that students *do not have to* interact with the simulation (in action or plot panels) in order to extract values. Values were given in the "info" panel. Our goal was to help students master, through the activities, scientific process skills and reinforce their procedural knowledge. Nevertheless, the clicks in this category of actions were recorded in order to find out if they were used and how. As it was expected, the use of these actions was at minimum.

We consider as relevant to the problem all clicks that are on the projectile or at the target in order to check the coordinates. Also, clicks like enabling the velocity vector for example in WS-4 where we explore the final velocity, are considered relevant to the problem. All other clicks, i.e., at any point of the trajectory or anywhere on the panel, are considered as explorative clicks.

In general, a few clicks were recorded, much less than the clicks in "settings" or "handling." The difference is in WS-8. There is an encouragement in WS-8 to use all areas of the simulation in order to confirm the measurements in multiple ways. This explicit prompt led students to use this category of actions more. A total of 94 clicks were recorded, about 9 clicks per student in a single WS. One third of them were exploratory clicks, while the rest (58) were considered relevant to the problem. In Fig. 18.6 we see the number of actions per WS in this category.

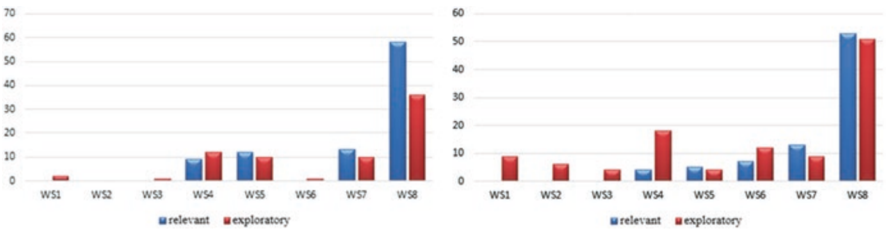


Fig. 18.6 Clicks on phenomenon (left) and on plots (right) per worksheet

Analysis of Clicks in Representations Panel (Plots)

For the same reason as clicks in the action panel, clicks in the representations panel are few. Here, the clicks of selecting the type for graph related to the measurement or clicks on the plotted curve are relevant to the problem. All other clicks on the graph panel are considered as exploratory.

Students are generally not familiar with the graphs especially in extracting data out of them, and therefore, these actions were not preferred, and only a few clicks were recorded in WS 1–7. The difference is again noticed in WS-8, where the above mentioned prompt was given. The number of clicks was increased substantially (104) corresponding in about 10 clicks per student in a single WS. Fifty percent of these clicks (51) were exploratory and the rest were relevant to the problem (Fig. 18.6).

Exploratory Actions

As mentioned before, all the actions (clicks) that the students made to the simulations can't be characterized as relevant to the problem. There are clicks in all categories that the reason behind them seems to be different from leading to the solution of the problem. We call these clicks explorative.

From our results, it seems that when students encounter something unfamiliar (new simulation, new variable, new phenomenon, or new strategy), they tend to explore it before they focus on the problem they have to solve. Exploratory clicks, grouped per category and per WS, are shown in Fig. 18.7.

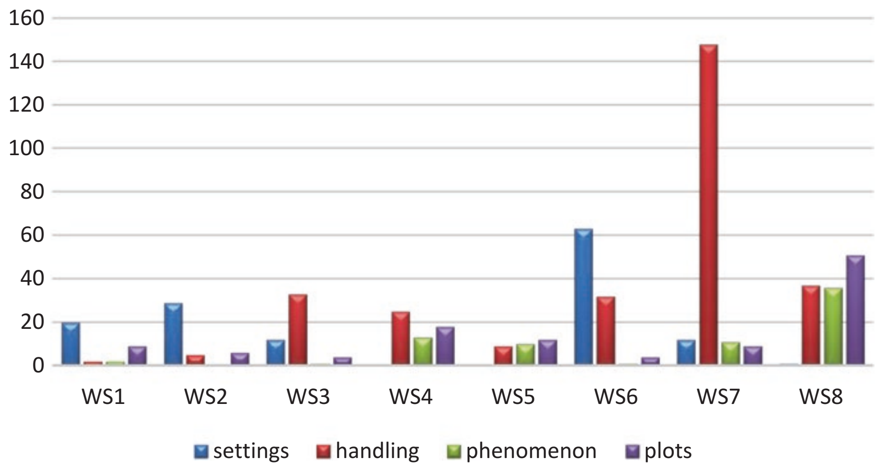


Fig. 18.7 Exploratory clicks per category for each worksheet

In the first two worksheets, we noticed some clicks before the first click to play button. This is the first time students see the simulation and try to explore it. In settings, explorative clicks cover the values of the available variables, like the students are trying to explore the range of each variable. Since the change of a value in the settings has a direct visual effect in action panel, we believe it might have seemed interesting for the students to watch.

The second increase in the exploratory clicks on settings was observed in WS-6; 60 clicks were recorded resulting in an average of about 5.5 clicks per student. In WS-6 a new parameter (the mass) was introduced for the first time. Though students *knew* from theory that the mass is not affecting the horizontal throw in the absence of air drag, students tend to explore the effect of the newly introduced variable.

In WS-7 we have the introduction of a new (to the students) phenomenon: the effect of air resistance to projectile's motion. The number of exploratory clicks in the settings was significantly increased. One hundred fifty clicks were recorded, which results in an average of 14 clicks per students. Most of these clicks are step forward and step backward as students attempt to observe closer the difference in the trajectory with and without air drag.

Another increase in exploratory clicks is recorded in WS-8, where a novel strategy was prompted: to seek for supporting evidence in all panels. Students seem to feel the need to explore the functionality of the two panels (action and graph) before they will use them.

Control of Variables

The control of variables (COV) is a processing strategy with direct implications to scientific reasoning. Recent approaches to scientific reasoning suggest that conceptual knowledge can elicit experimentation strategies, and appropriate use of strategies generates new knowledge (Lehrer & Schauble, 2006; Zimmerman, 2007). Given this interaction, context should have important implications for performance on reasoning tasks (Crocker & Knibb, 2016).

The rational "scientific" way for variable control is to isolate and manipulate a single variable while all other variables are held constant. In the two-parameter problems, one should set the first parameter to the smallest value, perform a stepwise increase of the second parameter, then set the first parameter to the next value, and repeat the process until all combinations are tested. This is usually referred as VOTAT (vary one thing at a time, Tschirgi, 1980). Other strategies are the HOTAT (hold one thing at a time, Tschirgi, 1980), AG (adaptive growth, Schunn & Anderson, 1999), or CA (change all, random). The understanding of COV strategy enables us to make a distinction between confounded and unconfounded experiments (Chen & Klahr, 1999).

In a two-parameter problem (like in WS-6), the relationship between the two variables ($v\underline{0}$ and h) to the range of the throw (s) is $s = v_0(2h/g)^{1/2}$. This implies that for a given value of s, there are an infinite number of pairs (v_0, h). This infinite

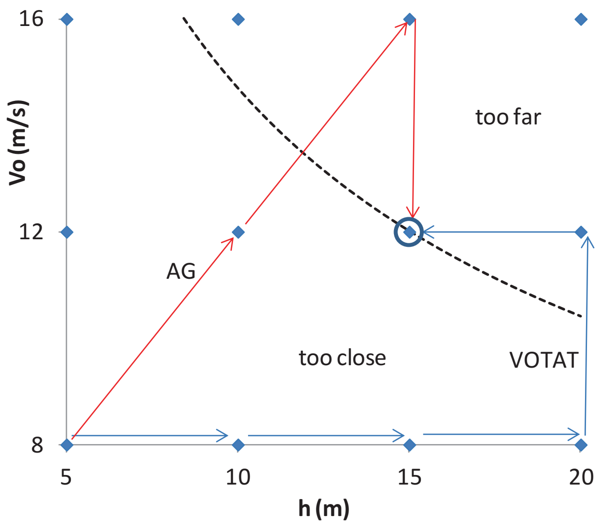


Fig. 18.8 Strategies for finding the solution to the problem

number of pairs is depicted by the dotted black line in Fig. 18.8, and sets the boundary between two regions: the projectile will land “too close” or “too far” from the target. This infinite number of pairs may be limited into a single solution by the constraint of stepwise change in variables; as both variables are changed in stepwise, the number of possible variable pairs is depicted in Fig. 18.8 by diamonds. Selecting the variable range and the variable step, only one of the possible pairs may coincide with the theoretically predicted curve. This pair of values is denoted by a circle in Fig. 18.8. In the problems where air resistance is encountered (WS-7 and WS-8), the expression for the projectile’s range is far more complex; however, there is always a boundary curve separating the “too close” and “too far” regions. The position of the boundary curve depends on the value of mass.

One way to find the optimum pair for launch speed and launch height is to try *all* the possible combinations (randomly or structured), record down the resulting outcome in a table, and later decide which of the pairs *is* the solution. Other ways for solving the problem is depicted in Fig. 18.8, where arrows indicate two possible strategies for changing the variables. The way indicated with the lower arrows may be conceived as keep increasing step-by-step the value for one variable (e.g., the launch height) until a change from “too close” to “too far” is reached. If no such change occurs when the variable reaches the maximum value (as in the case of Fig. 18.8), then increase the other variable (the launch speed) by one step. As can be seen in Fig. 18.8, this latter change causes the transition from the “too close” to “too far” region. Then keep the launch speed unaltered and decrease (by one step) the launch height, until the solution is reached. This way is similar to the VOTAT strategy.

Another possible strategy is depicted with the diagonal arrows in Fig. 18.8. This strategy is more like the adaptive growth (AG) strategy, which may be highlighted as "if successful, attempt a better outcome; if unsuccessful, stay the same or try something more basic" (Schunn & Anderson, 1999). This strategy applies to the success of design outcomes rather than understanding. In reference to Fig. 18.8, the "AG" strategy implies a change in both parameters (v_0 and h) leads to a closer to the target value (successful step) in the first application and a transition for the "too close" into "too far" region in the second one (unsuccessful step). In the third step, the application of VOTAT is adopted ("try something more basic").

Students' COV strategy is captured in Fig. 18.9. As mentioned, WS-1 was completed in classroom, with the help of the teacher, who suggested to the students to set all the values in an ascending order. The remaining worksheets didn't suggest any particular way to set values to the parameters. In Fig. 18.9 the term "VOTAT" is used for the application of the VOTAT strategy and the term "alternative" for the application of any other strategy (CA, AG, HOTAT) which leads to confounded experiments.

We noticed that, in level A, almost all students set the values to the parameter as they were instructed in WS-1. In level B problems, students faced for the first time two-parameter problems. A few of them managed to use VOTAT successfully, while the majority set the values randomly until all the available pairs of values were examined. In level C, there is an increasing trend for the number of students who used the VOTAT process and a decreasing for those who didn't.

After each WS there was a discussion with students asking questions or talking about their actions. This is not reflected in the WS, but we can see that it helped the students to better manage the next WS, in combination with the experience they gained. After all, the guidance provided by the teacher and the simulations have different affordances and both should be present for optimal support of learning (Lehtinen & Viiri, 2017). We noticed that when the problem is not fully understood, students often do not follow a global strategy in variable control, but rather they try

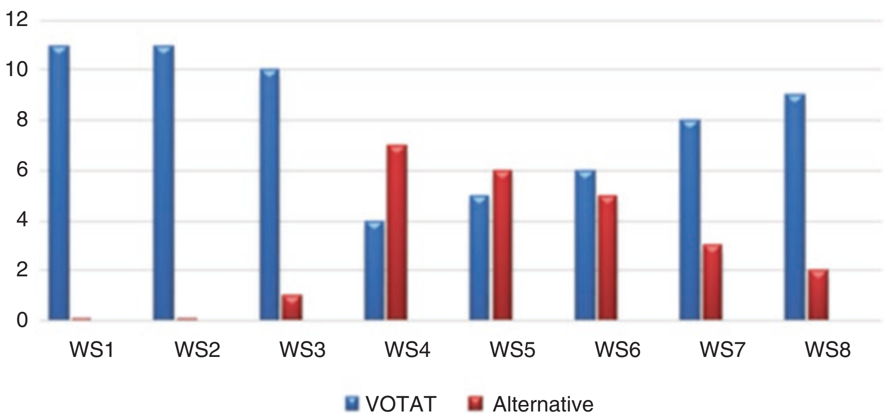


Fig. 18.9 Number of students per strategy for each worksheet

to find the solution by taking measurements at random. Many of them *did* find the solutions, but in an unorthodox way.

The students didn't know how to process multi-parameter problems in advance. The fact that the solution can be found even if the values are set randomly seemed to satisfy them. However, when they were encouraged to think of *a strategy* and use it, most of them have adopted the VOTAT strategy.

Conclusions

The analysis of the clicks in the log files of the activities revealed the factors that affect the number of clicks of each category and in total. Both the complexity of the problem (number of parameters) and the level of guidance (level of inquiry) exert influence on the number of actions—clicks performed in the simulations.

Concerning the first research question, the number of the available parameters of the problem has great influence in the number of clicks in settings and in handling. More parameters lead to more actions in these two click categories. The relevant to the problem actions of these categories are related to the number of parameters in levels A and B. The experience gained in these two levels by the students caused a small decrement at the number of trials they needed to find the solution in level C, as they tried to be more essential to the problem. On the contrary, the number of clicks in the phenomenon and plot categories was not affected by this factor. As expected, the design of the simulations chosen for the activities did not lead to actions of the phenomenon and plot categories in general. On one hand, we had students unfamiliar with simulations or managing and interpreting graphical representations. On the other hand, the ease of reading the values of the dependent parameters from the information panel led students not to prefer actions on the *phenomenon* and *plot* categories unless they were clearly prompted to do so.

The level of guidance provided by the WS is another factor which affected the number of clicks in each category. Concerning the second research question, the table provided by the WS for the students to write down the data they gathered defines the number of measurements they performed, therefore the number of clicks in settings and handling categories. Clearly, students made far more measurements than the minimum required. In cases where the solution was already found, students kept taking measurements filling up all rows in the table, as the WS prompted or implied them to do, especially in levels A and B. The significance of the guidance in the number of clicks is obvious in the phenomenon and plots categories. There were only a few actions performed by the students in these two categories, until the prompt in WS-8, which urged students to confirm their measurements in multiple ways.

Concerning the third research question, the relevance of each action (click) to the solution of the problem was also revealed by the log files. Except for clicks relevant to the problem, there were additional clicks that had explorative motivations. When students face a new parameter, they seem to explore the range of it, watch the effect of changing its value in the phenomenon panel, or explore the influence of the new parameter on the problem, before they actually start trying to find the solution. Explorative clicks were also noticed in WS-7, where the students had to deal for the first time with the effect of air resistance to projectile's motion. Students made many explorative clicks in handling category, trying to better understand the differences in the projectile's trajectory, with and without air drag. When students were prompted to adopt a new strategy in WS8 (to seek for supporting evidence in all panels), they first explore the functionality of the two panels (action and graph) before they will actually use them. In general, when students encounter a new situation, they try to explore it in order to understand it, before focusing on the problem itself.

As for the scientific process skills, the fourth research question, students seem to adopt the strategies they used at earlier WS to the next ones, which also concludes to fewer clicks in settings and handling categories at level C. At first, the lack of experience in multi-parameter problems confused students, leading to random actions, as the solution could still be found in that way. Despite that, in level C, many of the students adopted the VOTAT strategy, when they were encouraged to use *one* strategy in order to find the solution.

It was also observed that the students can deal with this kind of activities sufficiently, despite their lack of experience in simulations and multi-parameter problems, and they can gain significant procedural skills. Thus, inquiry-based learning, combined with educational technology, helps students to gain procedural skills, other than those offered by traditional learning. Students can easily adapt to this kind of learning and benefit from its advantages.

The study of the recorded clicks can give us an insight in the way that the students handle the simulations, the procedures they follow for solving problems, and the skills they gain. The recording of clicks is important, as not only it can give us the total number of clicks that the students made in order to complete the tasks but also the type of clicks they most used. More important is the analysis of all actions and their distinction regarding the reason behind each click; it seems that actions in the same category of clicks do not have the same motive, and not all of them are relevant to the problem.

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Chapter 19
Design, Implementation, and Evaluation of an Educational Software for the Teaching of the Programming Variable Concept

Stavros Markantonatos, Chris Panagiotakopoulos, and Vassilios Verykios

Introduction

The aim of this study was the design, implementation, and evaluation of an educational software for the teaching of the programming variable concept to 14-year-old students attending to the third class of junior high school. The designed software consisted of various interactive activities aiming to contribute to the students and help them understand the use of the specific concept. Through the software, students approached the programming variable as the content of a memory cell which was possible to be changed and was referred through a unique name. The RAM memory of the computer was represented as one-column array, stored variables could contain either numeric or alphanumeric values, and various interactive activities were implemented according to the different roles of the variables.

The programming variable concept is important in the learning of programming even to the introductory level that is suggested for the 14-year-old students. Understanding the concept remains difficult according to several studies (Ebrahimi, 1994; Jimoyannis & Komis, 2000; Jimoyannis, Politis, & Komis, 2005; Lahtinen, Ala-Mutka, & Jarvinen, 2005). Usually students' construction of the concept is based on their prior knowledge about the mathematical variable, but this leads to limited understanding, so they are not able to distinguish the differences that exist between the two domains. The mathematical variable is static as it represents a functional relation and has symbolic existence. On the other hand, the programming variable has a physical content as it refers to a computer memory location that stores

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values and can dynamically change during the execution of the program (Jimoyannis et al., 2005; Jimoyiannis, 2008).

Several approaches for the teaching of the specific concept have been suggested by the researchers. Alexouda (2010) developed various scenarios implemented with the Logo programming language for the students of the junior high school. Ben-Ari (2008) developed a program animation system with the Java programming language and created visualizations during the executions of programs for introductory programming lessons. Papadanellis, Karatrantou, and Panagiotakopoulos (2012) used the LEGO Mindstorms NXT kit for the teaching of the programming variable concept. Fesakis and Dimitrakopoulou (2005) supported that teaching-related subjects such as computer architecture could benefit 17-year-old students at the introductory programming lessons. Doukakis, Tsaganou, and Grigoriadou (2007) developed interactive animated analogies about the programming variable concept and the value assignment command, the conditional structures, and the looping structures. Grigoriadou, Gogoulou, and Gouli (2002) presented three different instructional approaches for introductory programming lessons. Jimoyannis and Komis (2000) developed various activities to help students distinguish the differences between the programming variable and the mathematical variable. Sajaniemi (2005), Sorva, Karavirta, and Korhonen (2007) and Kuittinen and Sajaniemi (2004) introduced the concept of roles of variables as the stereotypes of variable use in computer programs and suggested it as a promising pedagogical tool for introductory programming.

Theoretical Background

For the deeper understanding of the programming variable concept, students have to reorganize prior knowledge structures that hold from the domain of mathematics, reinterpret their presuppositions, and resolve their misconceptions. These are the key points of the conceptual change approach suggested by researchers such as Vosniadou, Vamvakoussi, and Skopeliti (2008) and Spiro and Jehng (1990).

Multimedia learning environments promote conceptual change (Vosniadou, Ioannides, Dimitrakopoulou, & Papademetriou, 2001). In these environments a conception can be presented with the use of appropriate analogies and visual representations. These analogies bridge the gap between the familiar and the unfamiliar. They facilitate learning of a concept as they provide the input to an inductive process, leading to an abstract schema which contains only those features crucial to the concept (Duit, Roth, Komorek, & Wilbers, 2001). To be more effective, the chosen analogy should consider students' prior knowledge, their experiences, and their interests. On the other hand, as Mayer (2005) denotes in his theory of multimedia learning, meaningful learning occurs when learners receive information presented in more than one mode, for example, pictures, graphics, and words (multimedia effect). In such conditions learners select pieces from the presented material, organize it, and construct coherent mental representations. Furthermore, learning is more effective, and understanding is deeper when the different means of multimedia representations represent different aspects of the concept taught. In this way students with different learning styles can approach the new concept according to their needs (Kozma, 2003).

In a multimedia learning environment, learners can follow different ways to access the learning material. They can move back and forth, review a topic that they missed, and find answers in problems that they could not solve. According to Spiro and Jehng (1990) and Jacobson and Spiro (1993), such a learning environment should provide a lot of different examples, related to each other and related to abstract, complicated concepts. Moreover, such an environment should provide scaffolding, appropriate help, and instructions to the learners, leading them to more advanced mental processes.

A multimedia application enhances learning as it motivates learners. The appropriate graphics, animations, pictures, sounds, and videos draw their attention. Furthermore, learners interact with application, change the pace or topic, choose the part they will get involved, and may follow different paths to reach at any point they want. They personalize the material in meaningful ways, and they check their assumptions, get answers to their problems, and come to conclusions. Simply, if learners have control over the presentation of information, this may result in increased learning. Interactive lessons tend to be dynamic, in the sense that they change in a variety of ways based on the needs of the learner or the teacher (Rapp, 2005). And this is more important especially for the novice learners, as they can benefit in multiple ways (Komis & Mikropoulos, 2001).

The Educational Software

The implemented educational software was designed in order to present a different aspect in teaching of the programming variable concept. It was based on the Cross-Thematic Curriculum Framework, on the high school computer science curriculum, and on the computer science school textbook for the third class of junior high school. The key point was the deeper understanding of the specific concept and not the learning of computer programming.

The chosen analogy was that of the representation of the computer RAM memory as a one-column array. In the cells of the array, different variables of different types could be stored, and they could be referred through a unique name. Except for the examples and the presented information, the implemented software was consisted of various activities aiming to motivate students and engage them. There was an effort to avoid usability problems such as disorientation, distraction, or cognitive overload (Scheiter & Gerjets, 2007). In order to avoid disorientation, the unit title was written on each page title. Also, the navigation was possible either from the menu which was always on the left side of the screen or from the appropriate buttons at the bottom of the screen. In that way the student could anytime trace his position, go back, or move forward. To avoid distraction, a pale color palette was chosen, and the same color pattern was used for the whole application. There were distinct fonts of appropriate size, and the most important objects on every screen were emphasized.

In certain points where there was a possibility for the student to have any problem, there was some kind of help which was diminishing as the student's experience and knowledge was growing. Finally, student's mistakes were just indicated, impelling him to try and fix them.

In the first activity of the software, students were interacting with a color mixer. By handling the appropriate pointer, they were adjusting the value of each of the basic colors (red, green, and blue) creating any color. The three values were varied from 0 to 255 and were stored as variables. In the next activity, students were prompted to draw a shape like a square, a rectangle, an equilateral triangle, and a circle by adjusting its dimensions, respectively. Each number was stored as a variable, and the shapes could be redrawn by changing the appropriate variable. This was an example of the basic principle of programming variables: something that can change value. In another activity a variable was counting the times a button was clicked (the variable as a stepper (Sajaniemi, 2005)), and they also had to decide on the variable's name. There was also a variation of the previous activity, where they could increase or decrease the value of a variable. Another activity was the well-known game "snakes and ladders." It was played by two students after they had determined valid names for three variables. Two of the variables were holding the positions of the players on the dashboard (the variable as a gatherer (Sajaniemi, 2005)), and the third was holding the value of the die. At the same time, on the left side of the screen, the one-column array was presented representing the RAM memory. It was containing the three variables, and beside there were their names. Variables of character type were presented in the last activity. The students could play the well-known game "rock-paper-scissors." The activity was started by defining six variables for the names of the two players which had to be valid, their choice (rock, paper, or scissors), and their score, respectively. Again, the values of all the variables were presented in the cells of the one-column array—RAM—on the left side of the screen next to their names.

Finally, there was a self-assessment test with feedback for the students in order to find out and fix their mistakes. The teacher could access the results of the tests and assess the teaching goals achievement.

Implementation of the Educational Software

The aforementioned educational software was implemented exclusively by the first researcher with Notepad++. It was consisted of PHP pages with HTML, HTML5, and MySQL και Javascript parts. It was supported by a MySQL database, which was created to hold students' data. The application was using the Apache Server and MySQL Server of the XAMPP application.

Research Goals

In this research we asked the following questions:

- Did the implemented educational software and the chosen analogy of the RAM memory as one-column array facilitated students to understand the programming variable concept?
- Did the specific implementation according to learning theory together with the activities facilitated students to understand the programming variable concept?
- To what extent differences in understanding were noticed between the students who were taught the specific concept through the implemented software and the students who were taught with the suggested way through the school book?

Methodology

In order to answer the questions above, the study went through an established plan. Two weighted groups of students were formed, an experimental group and a control group. There was a pretest, the intervention, and a posttest. The instrument of the study was an appropriate structured questionnaire (Robson, 2007). The students were assigned to each of the group according to the results of the pretest. There were totally 61 students from a high school of Patras.

The experimental group was taught the programming variable concept through the implemented software, while the control group was taught the specific concept through the school book and the use of the MicroWorlds Pro software. There was one teaching hour for each of the groups, according to the Curriculum. After the intervention, the programming course continued with the suggested way.

In the questionnaire there were questions about the programming variable concept, the place it is stored, if it is allowed to change its name, and if it is allowed for two variables to have the same name. Furthermore, there was a small problem about a football match, and the students had to define variables to store the names of the two teams and the score. After initializing the variables, they had to fill a table with the score according to the given scenario.

In the last part of the study, there were semi-constructed interviews for three students from the experimental group. The interview took part 2 months after the intervention so for the students to have completed the programming course and have used the programming variable concept in problem solving. The aim of the interviews was to collect some qualitative data about the implemented software, such as the opinion of the students about the implementation, whether it was interesting, and whether they were motivated to use it. In addition, they were asked about the parts that they liked most, about the parts that were boring, and if they faced any difficulties during their engagement with it.

Results

The misconceptions of the students as they arose from their answers to the pretest were concerning:

- The place a programming variable is stored.
- If it is allowed to change the name of a programming variable during the execution of the program.
- If it is allowed for two programming variables to have the same name.

For the processing of the questionnaires, appropriate variables for each question were defined. All the students before the teaching of the programming variable concept scored ($M = 5.38$, SD = 3.22), while after the teaching they scored ($M = 9.41$, SD = 3.39), $t(60) = -7.62$, $p = 0.00$. There was significant difference meaning that students from both groups were benefited from the teaching through the software and through the suggested way, respectively.

There was a significant difference between the score of the experimental group before the intervention ($M = 5.39$, SD = 3.49) and after it ($M = 10.94$, SD = 3), $t(30) = -7.49$, $p = 0.00$.

There was also a significant difference between the score of the students of the experimental group ($M = 10.94$, SD = 3) and the students of the control group ($M = 7.83$, SD = 3.07), $t(59) = -3.99$, $p = 0.00$.

Finally, as it concerns the part of the questionnaire with the football match problem, there was a significant difference between the score of the experimental group students before the intervention ($M = 3.19$, SD = 2.83) and the score after it ($M = 7.65$, SD = 2.73), $t(30) = -6.69$, $p = 0.00$.

The students' responses during the interviews revealed that the specific software was quite stimulating. They said it was user friendly and they didn't have navigational or disorientation problems. One of the students responded that "there was not a large amount of information, so we didn't have to read so much" meaning that there wasn't cognitive overload during the intervention. All of them responded that they enjoyed the game-like activities. One student said "it was nice, especially when we started playing," and he went on "the way RAM memory was represented was quite comprehensive." When they noticed that the games were parts of the activities and aimed to motivate them, one of them responded that "still the combination was intriguing."

As it concerns the learning outcomes, students responded that "it was an interesting way to approach the programming variable concept" with which they were unfamiliar. They recognized their misconceptions and they resolved them, a key point of conceptual change which was the aim of the intervention (Vosniadou, 1994). They emphasized that the introduction of the programming variable concept through the implemented software along with the teaching through the suggested material for the rest of the programming course facilitated deeper understanding. Finally, they indicated that the representation of the RAM memory which was always on the left of the screen was very helpful as they could notice the variables stored and the changes in their values, respectively.

Conclusion

As it concerns the first research question, responses to the questionnaire indicated that the students were benefited from their interaction with the implemented educational software. Also, the chosen analogy of the representation of the RAM memory as a one-column array, with the variables stored in its cells, facilitated learning and help students to overcome their misconceptions.

As it concerns the second research question, the specific implementation of the software along with the game-like activities motivated students. The simple but understandable environment was not distracted and didn't cause disorientation or navigational problems. Moreover, concerning for the part of the questionnaire with the football match problem, there was significance difference between the score of the experimental group students and the control group students, indicating that the chosen activities, especially the "snakes and ladders" and "rock-paper-scissors," facilitated deeper understanding and helped students in applying their knowledge to solve new problems.

As it concerns the third research question about the learning outcomes, the *t*-test analysis of the questionnaires for the students in the experimental group and the control group indicated that there was indeed a difference in understanding the specific concept. It seems that emphasizing the chosen analogy and demonstrating it along with the activities promoted learning, and that is the explanation for the differences between the two groups.

Finally, it should be noticed that the implemented software was not aiming to replace the suggested software which is used through the lessons. Instead, it can be useful as a complement, especially at the introductory programming lessons, motivate dialogue in the classroom about the programming variable concept, and suggest some extra activities.

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Chapter 20
Learning to Program a Humanoid Robot: Impact on Special Education Students

Julien Bugmann and Thierry Karsenti

Introduction

Parents expect schools to teach their children how to count, read, and speak foreign languages but also to facilitate their social integration. Yet in certain countries, students are still leaving educational systems without being truly prepared for the world of tomorrow. According to the OECD (2015), this is because many of them will not have learned the basics of coding. Learning to code involves a wide range of educational outcomes for students (Smith, Sutcliffe, & Sandvik, 2014) and has become compulsory in several countries, such as the United States, Great Britain, France, Sweden, and—only recently—certain Canadian provinces.

What's more, a number of studies and reports (Duncan & Bell, 2015; Mubin, Stevens, Shahid, Mahmud, & Dong, 2013) have shown that learning to code, including with robots, is important and even critical for students as it enables them to understand the omnipresent technologies that surround them every day and better prepares them to thrive in such an environment. This therefore makes coding a key competency for young people (OECD, 2015). However, scarce research has been found on the coding education of students with learning disabilities. Still, fewer of the studies have examined the educational impacts of robots on children who learn to code. Finally, a small number of studies discuss the effects humanoid robots have on this process, with the exception of research on students at a computer science school, such as that conducted by Nijimbere, Boulc'h, Haspekian, and Baron (2013).

Thus, this article presents the findings of an exploratory research project that is original when compared to other research on the matter. In fact, the research presented involved students with learning disabilities who learn to code in a very particular context, by utilizing a humanoid robot that speaks, listens, understands,

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moves, and dances. The objectives of this study were to describe (1) the benefits and (2) the challenges for students with learning disabilities while learning to program while using a humanoid robot. The interest of this project is therefore pivotal, to the extent that it has been shown above, that learning to code is an especially important student outcome for future success. Also, coding with robots can be extremely rewarding and beneficial to learners. Finally, such an initiative has yet to be described in the literature.

What Are the Educational Impacts of Learning to Code?

Before discussing the educational implications of coding, it is important to clarify any potential linguistic misunderstandings. Certain French-language researchers insist on the difference between the French terms for *programming* and *coding*, where programming is expressed in code, or a series of instructions written in computer language, to communicate with various technologies. However, in English, this distinction is rarely if ever made. Indeed, Microsoft uses the terms *programming* and *coding* interchangeably. The purpose of this paper is not to discuss the semantics of computer programming; it is mainly (and only) concerned with the potential benefits of this practice. As such, the term *coding* will be used to designate any activities relating to coding and programming.

Coding involves telling a computer, smartphone, application, or website what must be done, at a given time, in response to a specified action by the user. While coding, a given tool is being instructed to behave in a certain way. At a time when new technology is ubiquitous, it would seem critical to understand how this new group of tools works and how any given reaction occurs. For example, while using a smartphone, computer, and tablet, social network like Facebook, or an application as commonplace as word processing software, codes, invisible to the user, are generated. Understanding, if only partly, what this coding entails and how these tools work and, in so doing, achieving increased control over the range of technology present in everyday life render users far more active than passive. Because tomorrow's jobs will be shaped by technological logic, it is vital for the future of young and old alike to understand the so-called computer logic.

It is for this reason that learning to code has become a classroom mainstay. As will be described, it is relatively simple to become a creator, regardless of age, or whether or not the learner has a learning disability. Initiated by Seymour Papert several decades ago, this education in computer logic, often referred to as "computational thinking," is expanding steadily today thanks to software like Scratch, or ScratchJr, and is making its way into classrooms faster than ever before. Papert's work focused on the learning of computer logic with a small turtle called LOGO, which users learned to move through coding. The processes involved in moving the onscreen turtle could be fun and highly creative in addition to showing the user's process. Newer software, like Scratch, uses this same learning logic, but with increased realism. Much research has been conducted on the potential benefits of these tools for users (see, e.g., Ruf, Mühling, & Hubwieser, 2014; Saez-Lopez, Miller, Vázquez-Cano, & Dominguez-Garrido, 2015).

At the same time, certain countries have adopted "coding education," making it a required skill for students. In Canada, this is the case in British Columbia and Nova Scotia, where "coding in school" is part of a broader strategy designed to better prepare young people for the future. Learning to code is of great interest to these students, as it enables them to better understand the world they live in and better anticipate the future and all it entails so as to better prepare them for tomorrow's jobs.

Some researchers have shown that coding education is increasingly essential for students (Falloon, 2016) as it helps them understand the world around them and better prepare them to navigate a future society in which technology will be ever-present, thus making coding a fundamental skill for young people (OECD, 2015).

Finally, a number of studies have shown how learning to code benefits student learning (Moreno-León, Robles, & Román-González, 2016). Some of the main benefits are seen, for example, in mathematics (problem-solving, attitudes toward mathematics, a sense of competency, etc.), as well as in improved problem-solving skills.

Learning to Program a Robot

Learning to code involves more than designing a story or video game on the computer screen or a tablet. Coding is above all what makes it possible for students or anyone to create computer software, apps, and websites. A browser, an operating system (OS) on a computer, any app on a phone, Facebook, and any website are all made possible with code. Here's a simple example of code, used in a majority of textbooks, written in the Python coding language:

```
print 'Hello, world!'
```

Many coding tutorials use this command as their very first example, because it gives one of the simplest examples of code students can have—it "prints" (displays) the text "Hello, world!" onto the screen. While learning to code can appear as simple of displaying a few words on a screen, it can also involve programming a robot. Robots can be programmed simply, intuitively, and pedagogically. An example is the Dash robot, which can be programmed by students using user-friendly, free applications. Students can program the robot to maneuver an obstacle course imagined by the teacher, based on certain indications, etc.

Today, as with *Dash*, many robots are used to support coding education and make it a more authentic process. These include *Bee-Bot*, *Lego Mindstorm*, *Lego WeDo 2.0*, drones, *Sphero*, *Probot*, or even *Ozobot*.

Applications have been developed to help users learn to code at the same time as they control the robots.

By necessity, these robots have gradually made their way into educational institutions, and many researchers have studied their potential educational impacts on users. For example, this is the case of Komis and Misirli (2013), who studied the program construction process by kindergarten-aged children who used *Bee-Bot*-type robots; Kim and Lee (2016), who analyzed robot use and its positive effects on geometry teaching; and Kradolfer, Dubois, Riedo, Mondada, and Fassa (2014), who examined the effects of the *Thymio* robot on teachers. The latter study concluded that robots help students with disabilities to follow a conventional curriculum. These researchers also demonstrated that teachers lack institutional frameworks for and training on the use of robots in the classroom.

A literature review by Toh, Causo, Tzuo, Chen, and Yeo (2016) on robot use in early childhood education revealed that the benefits of such tools can be classified in four key categories: cognitive skills, conceptual skills, linguistic skills, and social skills. The authors further highlighted the fact that these robots help all learners develop an understanding of scientific processes and mathematical concepts and an interest in engineering.

These conclusions suggest that using robots can be effective in terms of learning, a finding confirmed by Kazakoff, Sullivan, and Bers (2013), and foster a positive attitude toward coding thanks to a tool like the website code.org (Kalelioğlu, 2015), which also gets kids coding in a range of situations.

Robots with Limitations

Despite all the educational benefits of robots, some, like Blue-Bot or Ozobot, come nowhere near a human level of functioning, as their movements are most often limited to those of a remote-controlled car: forward, backward, right, or left. In a world where robots with humanoid forms are becoming part of public (department stores, conferences, etc.) and private places, it appears necessary to bring young users into closer contact with these new technologies.

Moreover, beyond “bots” that function like remote-controlled cars (forward, backward, left, right, etc.), a few studies have used more sophisticated robots, referred to as social or humanoid robots (Shiomi, Kanda, Howley, Hayashi, & Hagita, 2015). Humanoid robots are human in shape: they have a head, two arms, two legs, and can stand. Sometimes their faces have human eyes and mouths. Even their “voice” can be adapted and modulated.

One question remains however: of what interest are humanoid robots in education? First and foremost, as mentioned in the introduction, these technological innovations are increasingly present in today’s society and because they will most likely shape the world of tomorrow. Second, early research suggests that these tools are likely to have numerous positive effects on young users with regards to the development of both technical and social skills. These two competencies will make it that much easier for children to make their way in the future. Finally, a number of researchers have used the NAO humanoid robot for educational purposes, particularly among subjects with autism spectrum disorder (ASD), as will be shown below. However, all the projects that have involved humanoid robots concern robot-learner interactions (Shamsuddin et al., 2012) rather than robot programming by students, an aspect that is paramount to this study's originality.

Most Studies on Humanoid Robots Focus on Children with an Autism Spectrum Disorder

Because humanoid robots look like a person but don't have the same characteristics (e.g., empathy), they make excellent allies in teaching children with an autism spectrum disorder. People with ASD experience qualitative alterations in their social relations as well as in their verbal and nonverbal communication (Caudrelier & Foerster, 2015; Centelles, Assaiante, Etchegoyhen, Bouvard, & Schmitz, 2012). As a result, children with autism have difficulty with social interactions, prefer repetitive games, are subject to communication disorders, and lack interest in other people (Caudrelier & Foerster, 2015). According to Caudrelier and Foerster (2015), a robot can replace the educator in teaching skills to children with ASD and, in particular, can make them more conscious of their body or help them develop their sense of touch, as was the case in the work of Robins, Amirabdollahian, Ji, and Dautenhahn (2010). Caudrelier and Foerster (2015) refer to the robot's contribution to autism therapies as "crucial," especially with respect to the individual's cognitive development. Furthermore, according to Shamsuddin et al. (2012), humanoid robots like NAO can sustain and initiate interaction with children who have ASD. Thus, the authors proposed interaction and/or movement modules designed to help autistic children interact with others. As a result, these robots can have an impact on the development of ASD children's cognitive, conceptual, linguistic, and social skills (Toh et al., 2016). Other research has examined how such robots contribute positively to these children's communications skills; for example, Fridin (2014) used an interactive robot as a teaching assistant that reads preschoolers pre-recorded stories. The study's findings show that the children enjoyed interacting with the robot, who turned out to be an excellent aid for the teacher. The work of Kim et al. (2013) confirms the social robot's positive impact on children with an ASD. The authors were able to demonstrate that using a social robot as an interactive partner increased interactions between the child with an ASD and the adult more so than a human partner or a video game.

Methodology

As mentioned before, the objectives of this study were to describe (1) the benefits and (2) the challenges for students with learning disabilities who learn programming with a humanoid robot. Given that research on students with learning disabilities entails a number of methodological challenges, a qualitative analysis method was thought to be best suited to this study (Trudel, Simard, & Vonarx, 2006). More conventional research methods in the humanities (e.g., questionnaires) are not always appropriate, in particular due to the difficulties these students encounter when filling out this type of data collection tool.

Participants

The school at which the research was conducted is located in the province of Québec, Canada. It is a special education school with an alternative approach adapted to students with learning disabilities where they can earn a vocational diploma.

This school helps students gain independence and assists young people in becoming engaged citizens and productive workers. Students who attend the school are highly resistant to formal schooling and environments. These aspects shaped the choice of the target sample for this research. This type of student is considered underprivileged and has more difficulty than others in becoming independent, joining the workforce, and, therefore, becoming a valued member of society. Giving these students more experience with technology and guiding them toward responsible and controlled use of digital tools may well be among the best ways of narrowing the divide between these youngsters and those who, today, enjoy easy access to such tools.

The research was conducted in September 2016 and June 2017 and involved 7 teachers and 79 of their students (34 girls and 45 boys). All students were learning disabled and were aged between 12 and 18 years.

Data Collection Tools

In this study, and to support our research objectives, five main methods were used to collect the data (Table 20.1).

Data Analysis Method

A qualitative analysis of the open answers to the interviews using the *QDA Miner* software was carried out. It consisted of a content analysis (L'Écuyer, 1990; Miles & Huberman, 2003), the semi-open coding of which was constructed using the participants' answers in relation to the research objectives.

Table 20.1 Main data collection methods

Data collection method	Frequency
Filmed observations (twelve 90-min sessions) during which students learn to code with a humanoid robot	Twelve 90-min sessions with 79 students
Group interviews with the teachers	Two 30-min sessions with 7 students
Group interviews with the students	Four 25-min sessions with 79 students
One-on-one interviews with the students	Four 5-min sessions with 79 students
The completion status for skill levels associated with robot programming	79 documents issued
Trace analyses (Jaillet & Larose, 2009) with the statement of programs carried out by students	Recording and screenshots of programs created by students using the *Choregraphe* software

Strengths and Limitations of the Methodology

One of the main strengths of this study is the specific research methodology employed. Research findings were enriched and triangulated by the fact that all members of the school were involved, by the one-on-one and group interviews, and by the filmed observations. Moreover, as stated previously, the use of a qualitative methodology only adds to the relevance and interest of the research project (Trudel et al., 2006). However, certain limitations are associated with these methodological choices. The work on the participants' perceptions remains a limitation which was offset, at least partially, by cross-analyzing numerous data (interviews, video recordings, student performances, trace analysis). All participant answers were collated in order to identify any discrepancies, where necessary.

The Process

The NAO humanoid robot created by Aldebaran Robotics (now SoftBank Robotics) was chosen for this study. The robot is 58 cm high and weighs 4.8 kg. It is equipped with two cameras, various sensors, and microphones so it can hear what is happening around it, see, and recognize the person(s) and object(s) in front of it. As such, it is also—and especially—able to interact with humans. The NAO robot is used almost exclusively in the academic milieu and can be programmed by any user, even children, via proprietary software called *Choreographe*. In the literature, there is no mention of primary- or secondary-level students having been involved in the programming of this robot. The assumption that this study was based upon was that the students would be able to program the robot to speak, move, etc., thanks to the *Choreographe* software. The remaining challenge was to motivate the students.

The main goal of the project was to use this robot to get students with learning disabilities interested in computer science and to introduce them to coding while ensuring they had fun. This practice is relatively rare. As mentioned earlier, this robot is usually used passively by students (children are not asked to program them). This is the case of the project conducted with autistic students, in which interactive and/or movement modules encouraged child interactions with the robots (Karsenti, Bugmann, & Frenette, 2017; Shamsuddin et al., 2012). The NAO robot has also been used with students who have difficulty writing, but that project did not involve teaching them to code (Lemaignan et al., 2016).

Making the Process Fun and Educational

To monitor the use of NAO in class, the curriculum *Become a NAO Master* (Fig. 20.1) was created. There are ten levels in the curriculum, each consisting of three intermediate steps which students must carry out (Fig. 20.2). Therefore, every student had 30 activities in total to complete (10 levels × 3 activities/level) before achieving the highest level and becoming what was coined a "NAO Master." The levels enabled students to gradually discover and perfect the programming method for the NAO robot. Thus, the first level only required them to interact with the robot using voice command, physical manipulation, and the programs installed on the robot. The purpose was to stimulate not only the students' language skills with a digital tool but also to help them understand how this type of robot hears and understands. This was a critical step in the students' understanding of how computer science and programming work.

Fig. 20.1 NAO Master program called "Become a NAO Master"

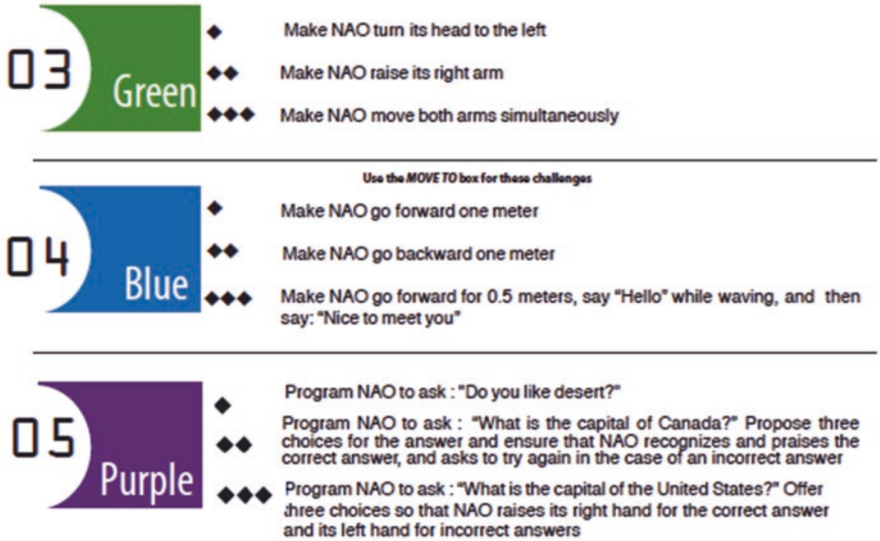

Fig. 20.2 Example of the activities that had to be carried out by programming the humanoid robot

Three manuals were developed to support users with all aspects of the *Choreographe* software: one general teacher guide, one student guide, and one answer key for teachers. The general teacher guide included all the information necessary to reach the various levels as well as advanced functions, whereas the student guide focused more on the levels to be achieved and gave students useful strategies to attain them. Students could thus refer to the guide to carry out a given activity, leading to completely independent work. In addition an answer key was designed to quickly validate student work. This guide showed teachers only the programming boxes to be used and the order in which they must be programmed.

From a technical perspective, these additional documents were published on touch tablets allowing students to quickly access the activities and any related instructions.

Bracelets marked “NAO Guide” were also ordered in corresponding to the various levels in order to stimulate the students and reward them as they progressed though the activities. As soon as they succeeded with one level, they received a bracelet bearing the name and color of the level as well as visuals associated with the NAO robot. The bracelets were intended to motivate students and push as far as possible within the proposed activities.

Results

After processing and cross-analyzing the data collected during this action research, a series of benefits and drawbacks to coding education using a humanoid-type robot for secondary-level students in a special education program were identified.

Among the many advantages discovered with this project, the top ten are presented below. Indicative student statements are also given to corroborate the findings.

1. Increased student motivation to attend school and a highly positive group ambience during the work sessions. Students found it rewarding to take part in an activity that was both fun and different from anything else they had experienced before, as witnessed by the statements gathered:

   - "I like programming NAO."
   - "I like to work with NAO—you can do a lot of things with it."
   - "It was fun."
   - "I liked making it dance."
   - "I liked making it move."
   - "It's a workshop I really liked."
   - "I pretty much liked everything."
   - "I liked programming it to dance."

   Increased motivation was also observed when many students went on to pursue other coding projects, outside mandatory class hours.

2. Increased collaboration among students and between students and teachers (Fig. 20.3). For example, 100% of students observed did collaborate with their peers to achieve the 30 tasks (challenges) they faced.

   - "It's important to work with my friends to achieve the levels […] otherwise it's not possible."
   - "We help each other a lot […]."
   - "We need each other to get to the next level […]."

3. Greater student autonomy and increased compliance with instructions (particularly as regards following the methodology skills necessary to achieve a given level). In the school yearbook, one classmate's comment about a friend effectively summarizes the relationship between the NAO robot and the students:

   > At school, he has a little brother called NAO, who takes care of him when he no longer wants to work in his schoolbooks and he does great programming.

4. Better problem-solving skills. Students had to find solutions to the problems they encountered when programming and had to understand why some coding did not work.

   - "Programming a robot […] it means to find solutions to problems […] we became better at solving problems."
   - "We became better at finding solutions to the tasks [problems] presented to us."

5. Enhanced creativity when working with a humanoid robot (i.e., Fig. 20.4).

   - "I feel that I can create many things with the robot."

Fig. 20.3 Students working with the humanoid robot

Fig. 20.4 Students programmed the humanoid robot to create a dab

– "I had the chance to create a "dab" with my friend […] we had fun doing it."

6. Improved reading and writing skills, but also verbal communication skills, particularly when students had to program the robot to communicate (writing text,

adapting vocabulary, punctuation, etc.). “I like it, because when you talk, it responds to what you’re saying.”

- “I liked making it have conversations with us.”

7. New coding and computational logic skills acquired through programming the robot.
8. Improved skills in the area of research and information organization (to carry out the tasks requested of them).
9. The development of various mathematical skills, notably in level 4, when the students were asked to program the robot to move forward or backward. In order to do so, students had to use coordinates on a Cartesian plane with X and Y data (symbolizing the distances and orientations for the robot).

The Remaining Challenges

Certain limitations are worth noting. One example of these is the complexity of *Choreographe*, the programming software, as confirmed by the comments of some students: “Some little things were hard” or “it’s hard” (to program it). Another challenge was the connecting of the robot. In order to connect it with the programming software, the students have to be on the same Wi-Fi network as the robot. This is a major challenge in schools due to numerous restrictions and safeguards. A solution was found by associating each robot with a single mobile Wi-Fi router that was brought to the classroom for each coding session, resulting in fluid, stable work sessions. The students were required to handle the robot gently and carefully because each is worth $6000—a challenging cost for any school. As a result, the student coders had to be accountable when working with the tool. Finally, it took time to adjust to the programming tasks through a number of trial-and-error experiences which were vital to finalizing the process, an aspect that had not been tested before.

Discussion and Conclusion

This research identified numerous educational benefits associated with the use of humanoid robots in an educational setting, and not just as it relates to “pure” learning of coding. In fact, the project was found to be extremely rewarding for students and teachers alike. In addition, and despite the challenges encountered in implementing this research, remarkable programming results in the classroom were observed, with some students reaching the tenth level of the curriculum within only two 3-h sessions. All these elements show that although the students were learning disabled, they were able to be highly efficient in learning, particularly in the novel field of computer programming.

Another key benefit of this tool is the high frequency of interaction between participants during the NAO robot programming sessions. The students were very playful and were much more cooperative than during their conventional classes. It should be remembered that these students tend to dislike school. The data collected show that using and programming a humanoid robot of this kind stimulates and fosters a strong interest in school attendance.

As such, the overall conclusion of this project is that using the NAO humanoid robot for coding education in a secondary school special education program is particularly beneficial for student learning. At a time when coding education is increasingly lauded and encouraged as much by political decision-makers as by researchers, this research was able to construct a process that can yield opportunities and growth for all students. Far more than a simple toy, the NAO humanoid robot may turn out to be a major ally in the education of young people, and not only with respect to the development of coding skills but also with the skills and knowledge taught in school that are valued in modern work life and society.

Yet very few students in schools today have been exposed to this futuristic robot, despite the interest of initiating all students, as future members of society, to this new technology, which may well be ubiquitous in tomorrow's society (Hood, Lemaignan, & Dillenbourg, 2015). In fact, such students—who are unable to follow a conventional school curriculum, need differentiated resources to learn, and who face problems functioning in society—must be led to a better use and understanding of existing digital tools, even more so than others.

Finally, it should be noted that the project did not end with the researchers' work sessions but continued, through video communications with the school's teachers and principal and the creation of new programs, some of which were innovative and complex. Other initiatives by the students using the robot will be the topic of future research.

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Chapter 21
e-ProBotLab: Design and Evaluation of an Open Educational Robotics Platform

Christoforos Karachristos, Konstantinos Nakos, Vassilis Komis, and Anastasia Misirli

Introduction

Children's learning in terms of programming is an objective nowadays, while environments that can effectively support the ability to understand these more profound concepts are limited. There are many and important reasons why computer programming, and particularly computational thinking (Wing, 2006), should be introduced as a subject in schools from the early ages. First of all, engaging a child with programming concepts helps him to strengthen his logical thinking. Although there are many programming languages that can be used in school, most do not have the proper features to be used by preschool and primary-school students. The difficulty concerns either the abstract structure of the programming language (e.g., difficulty in learning how to compose the command semantics) or the language development environment that is unfriendly to users of this age. Research findings support that programming for kindergarten children is possible (Fessakis, Gouli, & Mavroudi, 2013; Misirli, 2015), but it should be done within a specific framework that provides easy and tangible handling and is motivational for children (Misirli, 2015).

The most popular robotic constructions used as tools for the development of the algorithmic thinking of preschool and primary-school children (Table 21.1) consist mainly of closed-type software and hardware. This fact restricts their uses, which in any case are not inexhaustible, particularly in the case of young children whose capabilities to handle algorithmic concepts are limited due to their age. The main purpose of the already existing robotics platforms for preschool and primary-school children is their integration in the curriculum mainly as tools for introduction to the algorithmic thinking. Through this kind of educational tools, the child can be taught basic algorithmic concepts such as the sequential structure, yet without being able

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Table 21.1 Comparison of educational robotic platforms

Robotic platform	Open-source hardware	Open-source software	Construction robot	Age target
Thymio II	Yes	Yes	No	7+
BOE-bot	No	No	No	13+
Dash and dot	No	No	No	8–12
LEGO WeDo	No	No	Yes	
LEGO Mindstorms	No	No	Yes	10+
Scribbler 2	No	No	No	14+
Cubelets	No	No	No	8+
4WD Mecanum wheel mobile robot	No	No	Yes	8+
Robotis dream	No	No	No	7+
Bee bot/blue bot/pro	No	No	No	5–7+
KIBO	No	No	Yes	4–7
e-ProBotLab	Yes	Yes	Yes	5–14

to comprehend more advanced concepts such as the repetition structure or the variable concept.

Another major issue identified in these platforms is the fact that they focus only on one of the two important parts of the robotic system. Either the construction of the robotic device aims at the introduction of mathematical and engineering concepts or the programming of an already existing robotic construction through a programing pseudo-language aiming at the introduction of algorithmic concepts. Some examples of the first case are Cubelets (http://www.modrobotics.com/cubelets/) and Lego WeDo. Examples of the second case are BeeBot (https://www.bee-bot.us/) and Thymio (https: //www.thymio.org/en). Consequently, these systems focus on either the design and implementation of the robotic device using at the same time an existing programming (Logo-like) language or the use of a programming pseudo-language which is intended for a commercially available robot as part of the system and is used for the implementation of educational scenarios by educators and students.

A comparative analysis of basic robotic environments intended for ages 5–15, which is summarized in Table 21.1, indicates that there are no platforms that use open-source hardware and software and at the same time provide the opportunity to construct and program automated robotic constructions.

Taking all these factors into account, a platform which combines an open-source and low-cost microcontroller called Arduino with a user-friendly Logo-like visual programming environment was designed. The main idea was the dual use of the platform, so that the student on one hand being motivated to reproduce the robotic construction and on the other being able to program it.

The e-ProBotLab robotic platform is addressed for students ranged from 5 to 15 years old, in the 2 years of primary education and lower secondary education. Its purpose is to cover a part of the curriculum regarding the educational robotics in

STEM context and specifically concepts of information technology, robotic technology, and engineering. The main features of both the robotic device and the software take into consideration the groups of learners to whom it addresses and adapt to their needs. As for the manufacturing part, emphasis is placed both on the exterior appearance of the robot, which should be attractive for the children in a playful way, and the durability and reliability of the construction materials so that the final product has a compact and durable construction. As far as the programming part is concerned, emphasis is placed on the easy management and simple handling through a suitable visual programming environment. The commands of this environment cover basic concepts of structured programming approach. The use of the platform involves educators of various scientific fields like IT, mathematics, and technology, who can develop educational scenarios under the STEM pedagogy by approaching the concepts of algorithm, technology, engineering, geometry, mathematics, etc.

Overview of the e-ProBotLab Robotic Platform

Functional Requirements and Design Issues

This section explains the basic functional requirements that e-ProBotLab meets along with design issues that emerged from the needs of the target groups. Moreover, those factors will be described as it follows regarding (a) the robotic construction and (b) the programming environment:

(a) Regarding the robotic construction:

1. Open source hardware and software
   The core idea was the use of open-source hardware and software toward openness, joined with the low implementation cost that these tools provide.
   The basic requirement of the system is the use of open-source hardware and software toward openness, joined with the low implementation cost that these tools provide.
2. Wireless communication (Wi-Fi) of the robotic device with the software
   This type of communication was chosen because of the wider coverage provided by a Wi-Fi network compared with other types of networks as well as the support of different types of devices. Since Wi-Fi network technology already exists in Greek schools and in other educational settings, there is no need for additional equipment.
3. Usability and configuration of the system
   The usability of the system refers to how easily it can be used by educators and children. For this purpose, the robotic construction material should not be dangerous and heavy to use. The exterior of the construction was made of wood, a durable, lightweight, and child-friendly material.

4. Energy autonomy

   The robot must be energy-independent for a sufficient period of time. For this reason, battery-powered supply systems were chosen. The robot is supported by two independent power subsystems: firstly, by an energy supply subsystem that should feed the construction shaft system as the energy that motors need to move is quite large in relation to the energy consumed by the rest of the robotic construction. Secondly, a subsystem such as Wi-Fi that powers the microcontroller board and all the peripheral components was used. The reason why an energy-dependent solution on fixed energy sources by cable was not chosen is the flexibility that the platform should have when used by children and the real-play simulation that should be met.

(b) Regarding the programming environment:

1. Interface—ergonomics

   A basic requirement for the development of interface elements is the use of windows and visual communication. Since the platform addresses to preschool, where literacy and motor skills are under development, the use of icons was necessary. Therefore, a set of criteria was set up following features such as:

   (a) Large size to facilitate accurate movements.
   (b) Indicative icon for the command. For example, the forward command must be accompanied by an arrow indicating what the command does.
   (c) Verbal definition of commands. The words must be simple and understandable by the age range to which they address.
   (d) One-click command addition. Each command should be added/removed and configured with a single click.
   (e) Drag and drop commands so that the student can test and correct his programms.

   The interface of e-ProBotLab software is simple and makes the user feel intimate with the software. The use of colors, fonts, symbols, and icons is uniform.

2. Layout of elements on the interface

   The accumulation of large amounts of information like a large number of controls, links, and icons with active links on an interface can disorient the user and doesn't help him interact smoothly with the content. In e-ProBotLab software, the screen elements should motivate user navigation, thus increasing his interest.

3. Color usage

   In educational software, colors play an important role. Emphasis was given on choosing and combining colors because, apart from the aesthetic importance, through colors more ergonomics is given, the user's attention is attracted, the concepts and messages are emphasized, and the user is allowed to receive more information in less time. In addition, it has been shown that there is an effect of colors and graphics on the learning process (Dwyer, 1978). In the e-ProBotLab software, colors have been selected in harmony with each other. When starting the software, bright colors like orange, red, and light green are used that predispose the user. The activities use soft colors to avoid tiredness, and the basic color of most images is a shade of green. In all activities, the same color aesthetics is preserved. The button controls retain the same shape and the same colors throughout the application. At the same time, the images selected are representative of the actions they perform.

4. Feedback

   Feedback constitutes a key part of the user's progress and an integral part of the evaluation. Through feedback, the user gets information about his errors, as well as advice and tips for repeating a section. He can understand his level of learning, misunderstandings, and weaknesses. Feedback gives him the opportunity to try again until he achieves his goal. According to Kulhavy and Stock (1989), the feedback, in order to be effective, should include two types of information: (a) confirmation of the correctness or of nonresponse and (b) suggestions or guidance on the correct answer. Therefore, the e-ProBotLab environment has two types of feedback: (i) direct and (ii) supplementary. The former is related to the direct execution of the program from the robotic device. The latter is based on the recording of the user's actions by screen capturing them with the software and the ability to re-execute them.

System Overview

The user handles the robotic device through the e-ProBotLab web interface. During programming, user has the ability to modify his program either by deleting a command or by changing its order within the program. Students' interaction steps with the interface can be recorded with the screen capture feature of the platform. This video can then be used to analyze the student's way of thinking by teachers or by children themselves. The communication is carried out via a wireless network on which both the terminal devices in which the student works and the robotic construction are connected. The robotic construction receives in a serial mode the program path in an appropriate form. It saves the program locally (buffering) and executes each command with some time delay so as to enable the student to understand the execution of the individual commands. After receiving the feedback from executing the commands from the robotic construction, the student can recreate the program path and re-execute it (Fig. 21.1).

The whole process is coordinated by the controller component of the application (Fig. 21.2). The controller component is divided into two subsystems: Controller_A and Controller_B. The Controller_A works in the background, processing, and responding to events, which are mainly user actions, and it works at two times which are called construction time and run time, each time a new program is created. This has to do with the point on which the learner user has focused each time.

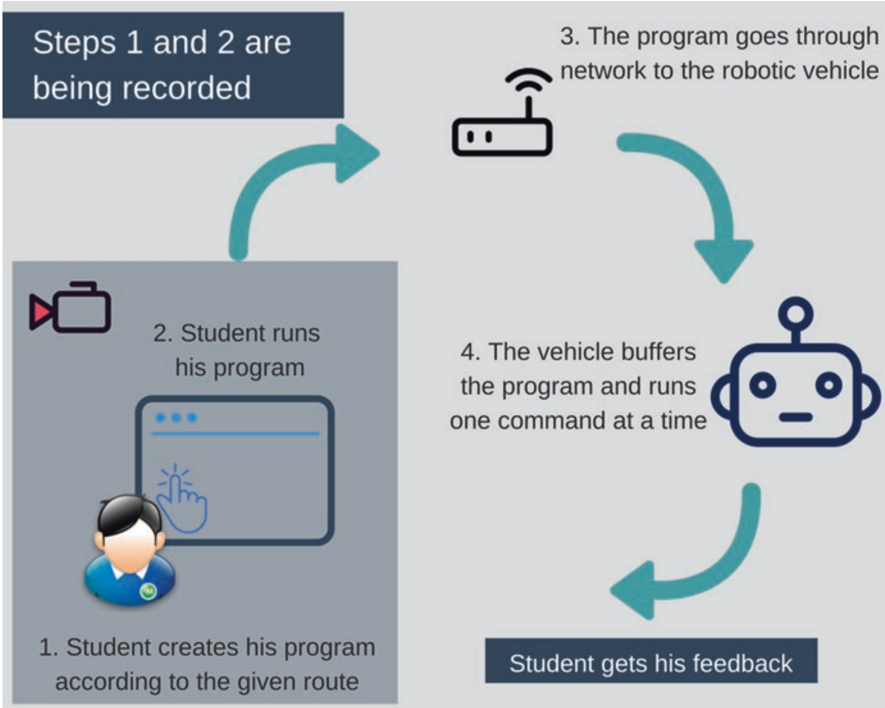


Fig. 21.1 System architecture schema

Construction Time

While the student creates the program, Controller_A creates the corresponding scenario in the background. Thus, by clicking on the F—Forward command in the background—the Forward command is added to the scenario program, and a Forward command box is added to the graphical environment of the interface. Furthermore, the student can modify the program by dragging and dropping the command box to another position or by deleting it. This will cause rearrangement of the scenario created in the background.

Run Time

When a student chooses to run the program by pressing the RUN button, Controller_A undertakes to create a communication channel with the robotic construction to which a fixed internal IP network has been preassigned. Afterward it undertakes to send the created scenario serially through the communication channel. Once the scenario is transferred, Controller_B, which runs on the robotic construction, undertakes to execute the scenario's commands one by one, thus the robotic construction performing the corresponding actions.

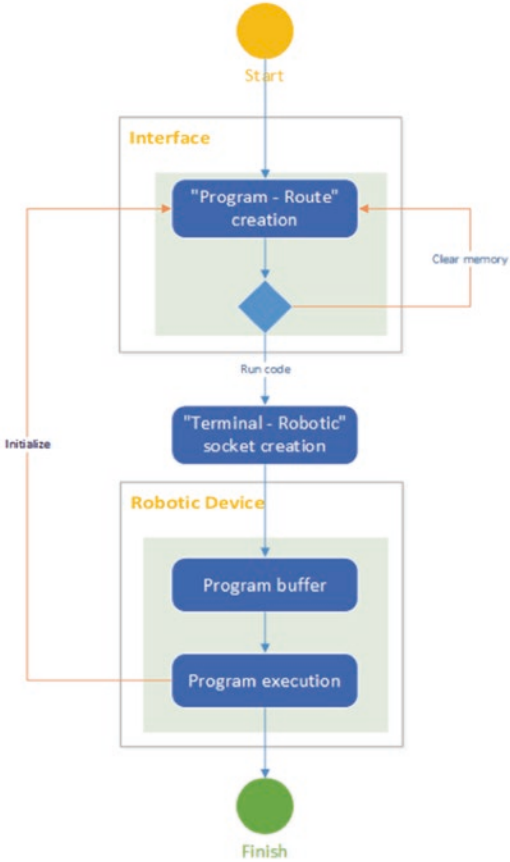


Fig. 21.2 Activities diagram

System Architecture

Interface Module

The platform's interface (Fig. 21.3) constitutes the user's point of interaction with the system. In the proposed model, the interaction is performed graphically using visual commands, the student can select the command he/she wants either by using a mouse, whether it is a fixed or a portable computer, or by gesture movements if it is a mobile device. This use arises from the need for simplicity that the system should maintain, since children at this age should not be burdened with learning how to use a difficult communication language, such as typing commands. This way the student can easily drag and drop the type of command he/she desires. Furthermore, he/she can rearrange his/her program by changing the order of the commands using the drag and drop feature again. This gives him/her the

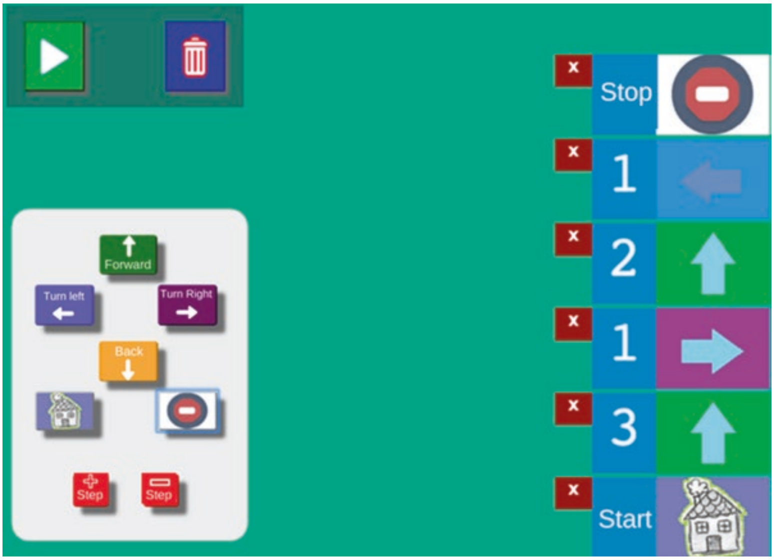


Fig. 21.3 Interface

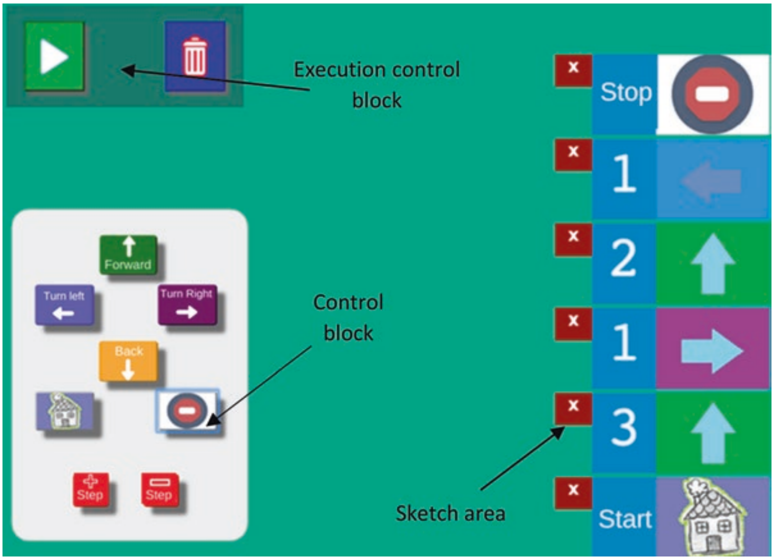


Fig. 21.4 The interface blocks

opportunity to reconsider his/her actions and review before finalizing the implementation of the program.

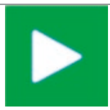
On the left side of the interface, there are two command blocks (Fig. 21.4). The lower block is the control block from which the commands to be used are selected.

For this reason, they are arranged in the shape of a cross to enable the student to understand what each command does. The upper block is the execution control block enabling the student to run his/her program or to empty the computer's memory (delete the program) and start creating it from the beginning.

Commands of Programming Environment (Table 21.2)

1. Control block

Table 21.2 Definition of commands

	Command icon	Definition
Control block		Move forward
Control block		Move back
Control block		Turn left 90°
Control block		Turn right 90°
Control block		Start
Control block		Stop
Execution control block		Run a route
Execution control block		Memory empty
Execution control block		Increase of step
Execution control block		Decrease of step

- Directional Commands: Robotic construction moves forward, back, left, and right. This version of the platform does not support motion at an angle other than 90°. It should be noted, however, that the openness of the platform allows the angular motion commands to be added in an easy way.
- The system has four directional commands. The first is the "Move Forward" command, which, when executed, causes the robotic construction to move 17 cm (execution step) forward. The execution of two "Move Forward" commands one after the other corresponds to an increase in the forward motion x2. This function also applies to the other directional commands. The second command is the "Move Back" command which causes the construction to move back about 17 cm. The "Turn 90°" and "Right 90°" commands stimulate the construction to make an in-line turnaround of its axis by 90°, respectively. This means that during the left turn, for example, the left wheel moves clockwise and the right wheel moves counterclockwise. The opposite happens during the right turn.
- Start/end commands: To consider a program is complete and in order for it to run, it must begin with a start command and finish with an end command. These two commands are declarative for the algorithm and must be added. It should also be noted that in a scenario there can be no more than one start and end command. There are two commands that indicate the start and the end of the program. The start is indicated with the home icon, while the end with the icon "forbidden."
- Step commands: The user can determine how many times each command will be executed. At this point it should be noted that the step command is not the same as the structure of repeating a set of commands, as this concept presupposes the existence of one or more commands in the body of execution. There is one command that increases the execution step and is symbolized by the red "+ step" icon and one that reduces the step and is symbolized by the "− step" icon.

2. Execution control block

Execution commands, empty memory commands: Once the student completes the program, he/she can run it by pressing the RUN button at the top of the interface. By pressing the RUN button, the system loads the program scenario that the students have implemented to the robotic device. The device executes the commands sequentially. Furthermore, the student can delete a command if he/she considers it necessary at some point in developing his/her solution. This is done by clicking on the X area at the top of the command. Finally, the program contains the memory empty and reboot command of the program which must be presented in such a way that the student identifies it with the memory of the computer and its emptying when the program is deleted from it.

3. Program creation space

Command Structure

The structure of the command block (Fig. 21.5) consists of three parts.

The first section on the left is called command deletion handler and is used to delete the command from the path stack. The second part of the command block displays the number of times the command will be executed. In this example, the command will be executed three times. This number changes by the corresponding step increment/decrease icons. As mentioned earlier, this number should not be confused with the concept of "command repeat" of computer literacy. The concept refers to the repetition of a number of commands. In the application, this figure represents the step that the robotic construction will perform each time, which can be varied according to the needs of the particular route. Finally, the third part of the command block displays the type of command to execute. Along with the three sections visible to the user, the command block also provides the ability to be moved, meaning that the user through the rearrange operator (which is invisible) can drag the command into the program creation space.

Screen Capture Option

The platform provides the function to record the student's movements until he finalizes his program. This feature creates a screen capture file that has stored student interactions with the interface. Any interested user can watch as many times as he likes the process of creating a program that the student has followed. The aim of this extra function is to allow the teacher to keep track of the student's way of thinking until the latter completes the program route. Thus, the teacher can perceive potential difficulties the student may encounter, either with misconceptions of using the tool or with incomprehensible algorithmic concepts, etc. This type of metadata can be used by the teacher to modify his/her teaching and then to design activities appropriate for each student.

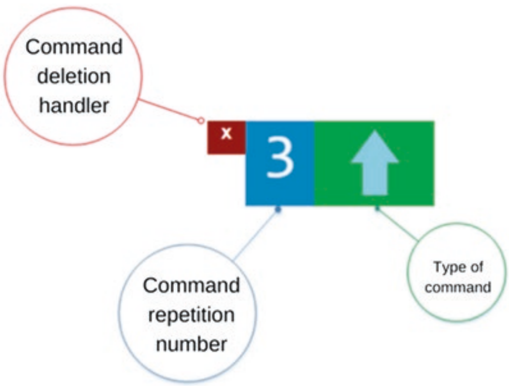


Fig. 21.5 Structure of the command block

Robotic Construction Module

The robotic construction (Fig. 21.6) of the platform consists of a single-board Arduino microcontroller and an open-source motherboard, with a built-in microcontroller and various inputs and outputs. Two 28BYJ-48 stepper motors are connected to the board. These motors can perform 512 steps per rotation, which gives high rotational accuracy. Motion and rotation accuracy is a basic requirement for robotic construction in every command execution. The execution step of the robotic construction is set at 17 cm, allowing the user to modify this value programmatically.

Wiring

The following diagram (Fig. 21.7) presents the basic wiring of the robotic construction. An additional circuit called H-bridge is being used in order to deal with the Arduino's digital pin problem in the construction's motor control (reverse of voltage).

More specifically, we can see:

- H-bridge pins 3 and 6 are connected to the left motor.
- H-bridge pins 11 and 14 are connected to the right motor.
- Pins 4, 5, 13, and 12 are grounded through the breadboard on the Arduino.
- H-bridge pins 2 and 7 are connected to the digital outputs 6 and 5 of the Arduino, respectively.
- H-bridge pins 15 and 10 are connected to the digital outputs 11 and 10 of the Arduino, respectively.
- H-bridge pins 1, 8, 16, and 9 are connected to a power supply.

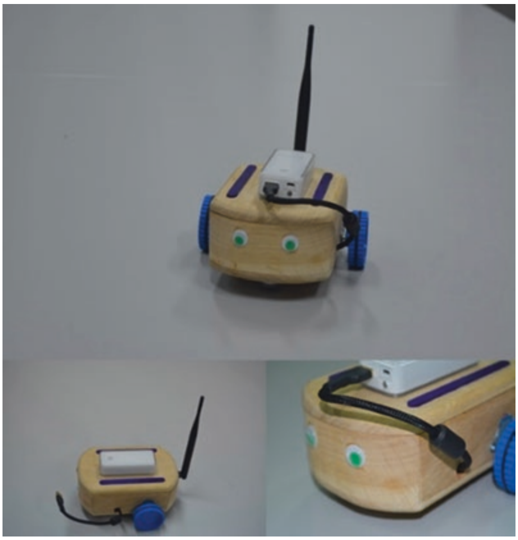


Fig. 21.6 Robotic device

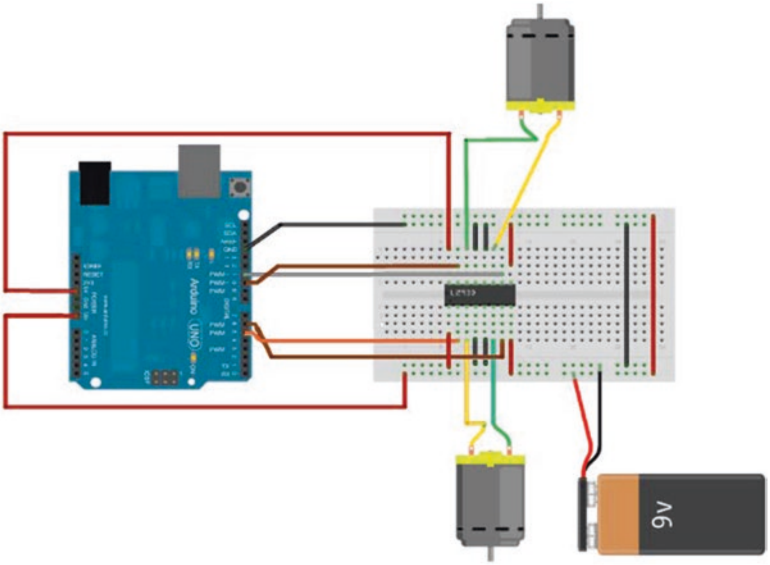


Fig. 21.7 Internal circuit board diagram

According to this wiring and the respective software program, which has been uploaded on the robotic construction, the robot is able to move forward and backward and to turn on its axis by 90°. It should also be noted that the electrical power input provided by the Arduino (5 V) is not enough to support the motors' movement or the power in the Wi-Fi module of the construction. As a result, an additional power source should be connected. Finally, as you can see in Fig. 21.7, the system offers expansion possibilities, the possibility of sensor addition, etc. in a very easy way for advanced users, since its hardware and its software are open source.

Robotic Construction Software

This chapter presents the basic software structure concerning robotic construction. The chosen architecture is the following: through the communication channel that has been installed between the work station and the robotic construction, each time students run their program, which is sent to the robotic construction in a form of array. An example of such a program is the following: [Start, F, F, F, R, F, F, L, Stop]. On the part of the robotic construction, the elements of the array are being accessed, one at a time, and depending on the element that is being accessed, the corresponding action function that has been set is: executed. For example, if the element F of the board is being accessed, then the function Forward (Fig. 21.8) is executed, which causes the robotic construction to move one step forward.

```
/*Function that moves the robotic construction one step forward/
void drive_forward(){
digitalWrite(motor_left[0], HIGH);
digitalWrite(motor_left[1], LOW);
digitalWrite(motor_right[0], HIGH);
digitalWrite(motor_right[1], LOW);
}
}
```

Fig. 21.8 Wiring code of command structure

The robotic construction possesses the function of storing a multitude of commands (buffering) and the function of executing these orders at a later time.

```
/*Function of construction repetition. This function is
executed repeatedly while the construction is in
operation/
void loop() {
for (int i = 0; i < 100; i = i + 1) {
if (Serial.available()>0){
state[i] = Serial.read();
}
if (state[i] == 'f') {
drive_forward();
}
}
```

The way of development supports the open-source model. More specifically, the robotic construction is independent from the work station and functions in an abstractive way in relation to it. The only condition that must be satisfied is that the user's program should reach the work station in the form described above. This means that a possible interface modification or construction modification does not affect the total system architecture. In this way, further movements (e.g., movement in angle) could be added into a future edition of the interface and the construction, without a negative effect on the system's stability. Moreover, as far as the construction is concerned, an easy update of its components is possible (e.g., the stepping motors can be replaced with other motors of greater power).

Communication Module

The wireless networking has been chosen as a solution to the communication problem among the various elements of the construction platform (work station and robotic construction). This specific demand arose since students should be able to interact with the device in the most flexible way, something that the wireless communication offers. A different form of communication (e.g., Bluetooth) hasn't been chosen on the grounds that, firstly, the Wi-Fi network provides a broader coverage in comparison to other types of networks and, secondly, there is the potential of multiple access from various devices. The Bluetooth protocol constitutes an alternative solution, since it is commercially cheaper compared to the Wi-Fi network and does not presuppose the existence of a network router. However, Bluetooth was not the first option, as the Wi-Fi network is an already existing and supported service at schools, and as a result, there is no need for extra funding for equipment purchase.

Educational Application of the e-ProBotLab Platform

The educational applications of the e-ProBotLab platform are focused into two main categories. The first category regards the development of programming abilities through the platform. The second category regards development of skills from STEM area, through the "reconstruction" of the robotic device. The former addresses to younger students (preschool and primary school), whereas the latter addresses to senior students (junior or senior high school).

Programming with e-ProBotLab Platform

Concerning the integration of the platform in the educational process, an educational scenario took place aiming to introduce students to the programming environment. Every teaching intervention is necessary for students to be familiarized with the environment before cognitive issues to deal with (Misirli & Komis, 2014). It is considered very important that both students and teachers use the platform functions easily so as to focus on the various educational activities that the scenarios deal with. For example, if the e-ProBotLab platform is used in order to introduce primary-school students to notions of geometry such as the notion of distance, direction, etc., it would be wise to use the first teaching intervention to familiarize the students with the platform.

The educational scenario aimed to introduce the e-ProBotLab to the students contains appropriate worksheets, and it was used with younger students, so as to evaluate the use of the platform at a first stage. Twenty (20) children 5–8 years old participated in the research having no previous experience with robotics. One (01) questionnaire for tracing previous knowledge and three (03) activity sheets were modified for the purposes of the research (Misirli, 2015). The educational material (mats and scenario) is used in their prototype form (Misirli, 2015).

Programming with the e-ProBotLab

Before starting implementing the educational scenario, the robotic construction was given to the students (Fig. 21.9). The students expressed their enthusiasm, and it seemed that the construction triggered their interest and they were curious to discover more things about it. They expressed their positive feelings by saying: "How nice it is…," "It is wooden…," and "It has small eyes, as well…." Most of the students wanted to discover more buttons (or control sticks) to make it work.

After their observation they asked questions such as "What does it do?", "How does it work?", and "How can I play with it?". It is worth mentioning that there was a student who asked: "What is this in the back side of the construction?". When the researcher answered "It is an antenna," the student wondered about the usefulness of the antenna. Before using the worksheets, we explained to the students that we use the computer or the tablet in order to get the e-ProBotLab to work. The students were asked to use whichever device they wanted (either the tablet or the computer). Almost all of the students chose to use the tablet, a fact that we did not meet with surprise, since children are familiarized with the portable devices.

First Activity Sheet: Children's Perceptions for the Basic Robot Commands

The purpose of the first activity sheet (Fig. 21.10) was to trace student's cognitive perceptions on the programmable robot, in particular about its function. In that way it would be assessed what they perceive, what every button does when pressed, and how intimate and easy the environment was for the students (Misirli & Komis, 2012).

The initial questions relate to their first impression of e-ProBotLab and what it can do. The students responded that e-ProBotLab looks like a car. Because of the impression created by e-ProBotLab, they answer correctly to the question "What does it do?". The spontaneous response of the students is: "Run" and "Move." However, no reference was made to the directions. At the instigation of the investigator, they gave a complete answer using the directions as well. The last question about the initial impression created by the robotic construction is how it can move. Kindergarten students did not respond to this question at all (either by ignorance or because they did not understand it). Primary students responded incorrectly and specifically referred to the material part (the wheels). Starting from the answers to the previous question, an introduction to the programming environment takes place. The worksheet then includes questions about what they perceive and what they think the icons do. The first question is if all the icons are the same. All students answered "No" and spotted the difference in colors. Most students were more observable and found a difference in the content of each button. The questions then concern the motion buttons (front, back, right, and left). All students understood very clearly and precisely the meaning and function of these buttons. The students did not understand what the button "Stop" did and what its usefulness was. This did

Fig. 21.9 Familiarization with e-ProBotLab

Fig. 21.10 Student work on the first worksheet

not make any special impression, as they had not dealt with programming concepts before. The next question was about the "Run a route" button. Students at first could not understand its meaning and role. Examples such as video and music play on the mobile or video on YouTube have been reported. The students immediately after this clarification responded that the robot started. However, the example mentioned above to a student (more experienced in computer use) has created confusion. As can be seen from their answer, they felt that by pressing the button again, the robot would stop. The Empty Memory button immediately prompts the students that something "Wrecks." After a clarifying question, it was realized that the students did not know what it was that was being erased. The last questions about the programming environment buttons involved increasing and decreasing the execution step of each command. In the first contact with the students, they could not understand its meaning and its role. To complete the detection of past knowledge, students were asked, "What do you think is a robot?". The picture given by the students about what a robot is wrong. Typical answers are as follows: "The robot is a toy" and "It has an antenna, we push it and it goes alone."

Second Activity Sheet: Experimentation with Basic Commands

Before working on this worksheet, a quick update to the students on what follows takes place. In the first activity, students experiment with e-ProBotLab (Fig. 21.11) and the programming environment. At the time they are given, it is noticeable that they do not use the step buttons, that is, the buttons found in the previous worksheet whose meaning they did not understand. After intervention/prompting on behalf of the researcher, they experimented with the operation of these keys.

They were then asked to answer the questions on the worksheet if they realized the meaning of the buttons and their usefulness. Students' replies indicated that they understood in a great extent the role of each button without further explanation for any of them. The next activity has to do with the "empty memory" button. Students were asked to work/experiment with this button. Initially, the students without having created a program clicked the appropriate button. There was an expected response "It doesn't do anything," "I do not know," and "I don't see anything." At this point, teachers needed to intervene. The students were asked to use some commands and then click the button that was mentioned. They immediately noted their response on the worksheet. Indicatively, some are listed: "it removed the buttons we put on it" and "it rejects the buttons we clicked." The third and fourth activity (Fig. 21.12) aims to check whether students can orient themselves in relation to the position of e-ProBotLab. These activities are of great importance for the development of the scenario as the movements and the paths to be followed by e-ProBotLab are directly related to the orientation in relation to it (front, left, right, left).

The students easily recognized which objects are located in the front, back, right, and left of e-ProBotLab and did not need any extra intervention. At this point we must emphasize the great importance and role played by two features of the robotic construction, the eyes and the antenna (Fig. 21.13).

Most students, on the question "how did you know what is in front, behind, on the right, on the left of the robot?" used the eyes and tail of the device in their answers, for example, "because the tail shows it." Then the students created the first complete programs that direct e-ProBotLab to follow the predefined routes (Fig. 21.14). Cardboard flooring was used for this purpose (Fig. 21.15). The first route required the students to direct the robot to move forward to reach the bench.

Fig. 21.11 The students are experimenting

The majority of students responded very easily and correctly. However, there were also a few students who, when creating the program, pushed the button forward only once.

They immediately realized their mistake and reiterated the exercise correctly. The next route required the robot to move back to the car.

Thereafter, students were asked to program the e-ProBotLab in a C-shaped direction toward the red bicycle. Students were faced with trouble in order to solve this exercise (Fig. 21.16).

Some used their thoughts directly and recorded the results on the paper, while some others (mostly younger students) got up, and as they moved the robot by hand, they were saying the steps to be followed (Fig. 21.17).

Two important points were noted. The first point that some students had difficulty with was the wrong perception of the left and right arrow buttons as they had not been seen in previous activities. They did not realize that these keys cause only a 90° rotation around the robotic shaft and not simultaneous turning and moving forward. By running the program, the students realized their error and corrected it by creating the program right from the beginning. The second point was the way the students created the programs (Fig. 21.18). Some students created the entire program and executed it, while others created parts of the program each time, executing them and continuing creating as shown below.

For students who followed the step-by-step creation and execution of the desired program, an intervention took place in order for them to understand that it was possible to create the entire program and then execute it. After the completion of these activities, students were asked to direct e-ProBotLab to the yellow bike. All students responded successfully. The last activity in this worksheet was the most demanding. Students created their own route by using their own items. The students were asked to place the e-ProBotLab in a position and plan their own route. This route must be executed by the robot by programming it. Students programmed the robot, and those who made a mistake repeated the exercise after they identified the mistake they had made.

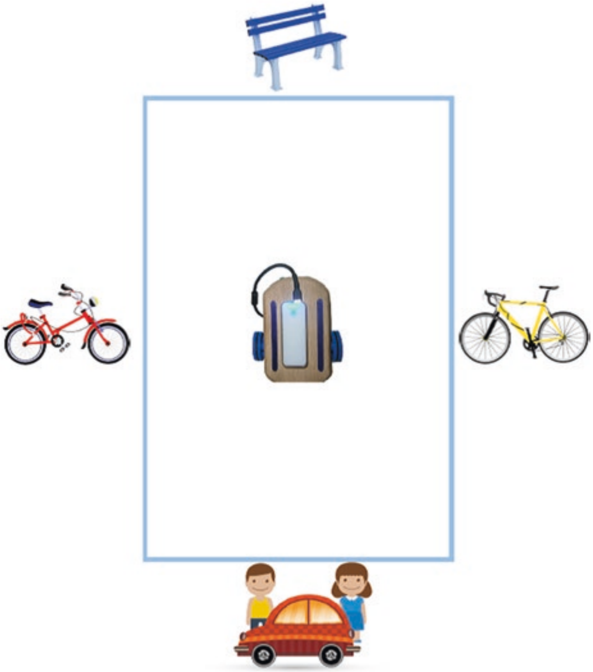


Fig. 21.12 Activities 3 and 4

Fig. 21.13 e-ProBotLab eyes and antenna

Third Activity Sheet: Problem-Solving

The evaluation activities of this worksheet concern the handling of robotic construction and its basic functions, i.e., it aims to assess whether students are able to handle the programming environment. This worksheet asks each student to indicate the commands needed to make specific routes by e-ProBotLab on the cardboard floor (Fig. 21.19).

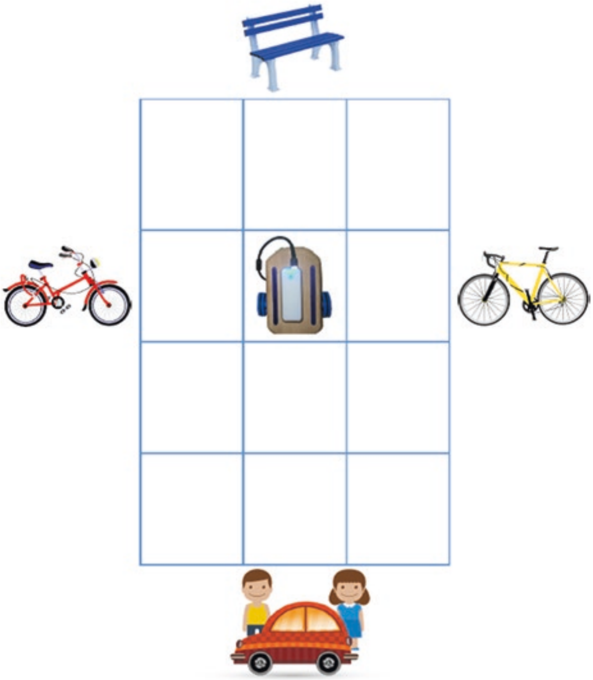


Fig. 21.14 The first track

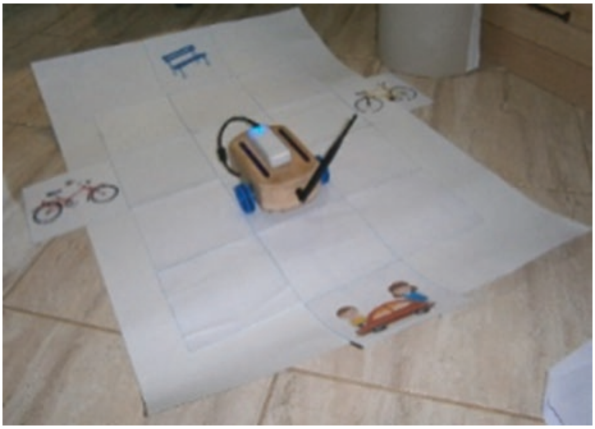


Fig. 21.15 The first track on a cardboard

They then implement the requested program on the computer (Fig. 21.20). The first activity included moving to the swing and then to the seesaw. The students responded positively to this activity.

Even students who initially found it difficult to test and repeat successfully managed to successfully program e-ProBotLab to follow the required route (Fig. 21.21).

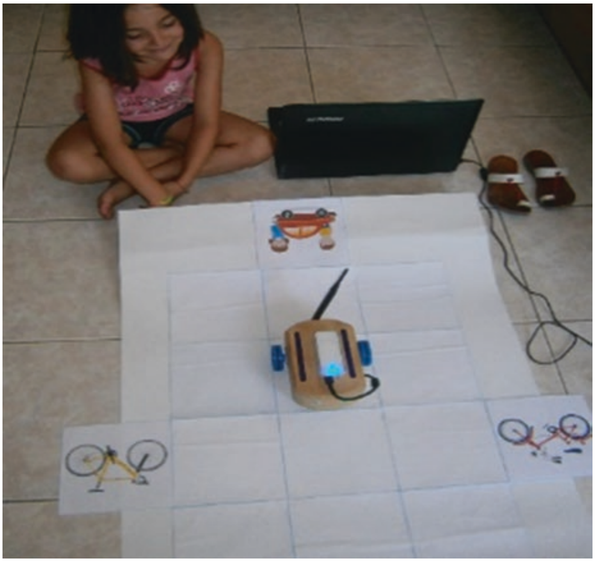


Fig. 21.16 Thought for the solution of the activity

Fig. 21.17 The way students worked

It is characteristic that the students who made a mistake in programming immediately recognized it with an expression like “I know where I was wrong,” “I found the mistake,” and “it went right, not left” and started again on their own the implementation of the right program.

In order to create the path, the students of the kindergarten initially moved their e-ProBotLab with their own hand and mentioned the movements they made. They then created the programs on the computer. It is worth noting that no student from the multitude of possible solutions used the backward movement. The second and third activities are in the same philosophy. The even more familiarized students constantly reduced their mistakes. It seems that there was now complete familiarity with the programming environment as they used it with ease. If they added a wrong command, they did not concern themselves with it, nor did they address the instructor, but they erased the wrong command or moved it to the right position or canceled the whole program and started from the beginning by themselves. The last part

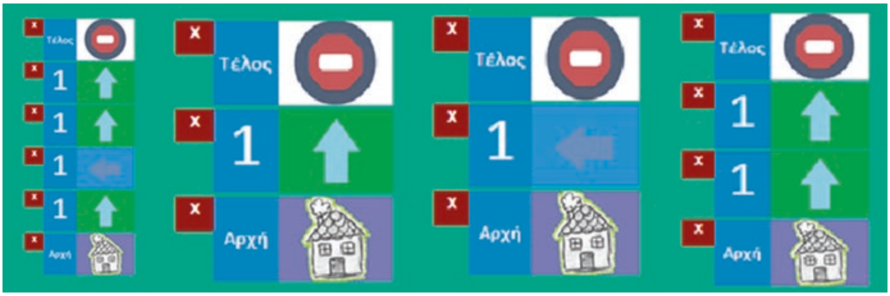


Fig. 21.18 The two ways to create and run a program

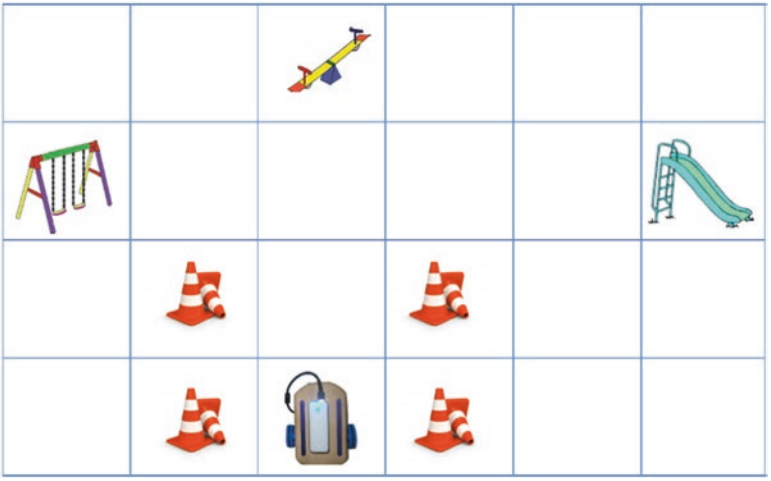


Fig. 21.19 The students' track

included True or False questions. As observed, the students as a whole responded correctly to all the questions except the first ones who encountered difficulties. Even though they used the step-up button correctly in the activities, in the True or False questions they answered incorrectly.

Conclusions of Educational Intervention

The educational use of the e-ProBotLab robotic construction in the framework of an educational scenario designed, implemented, and evaluated by preschool students and the first two grades of primary school was analyzed and studied. The analysis shows some important results:

1. The completion of the intervention ended up enabling students to identify movements of the robotic construction, to recognize how it works and how to handle

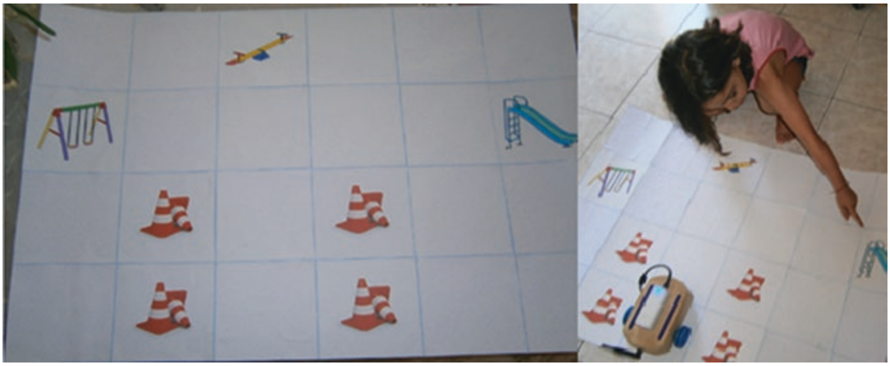


Fig. 21.20 The students' track and work

Fig. 21.21 The students' work

and control it. Specifically, during the initial questions about robotic construction, its functions, and how it was handled, the students had some ideas about what it was and made assumptions about it. After the intervention, the students clearly influenced by the training scenario activities largely recognize how e-ProBotLab works. All students completed their activities and any difficulties that were accomplished.

2. The presentation of e-ProBotLab before students' instruction has created enthusiasm and motivation to engage with the educational scenario. As it turned out in the final interview questionnaire, e-ProBotLab was the element of the "lesson" they liked most. Typical was the desire of some students to continue with other tasks at the end of the script. Additionally, some students expressed their opinion on what more could the robot "do," for instance, "Turn on the light in the dark."
3. e-ProBotLab was a handy tool for students who were familiar with how it worked in a relatively short time. Their handling seemed easy as the programming environment features clear icons/buttons. In designing the icons/keys, the only button that needs redrawing is the "end" button.
4. e-ProBotLab can be a useful and effective tool, as long as the teacher has the right planning and preparation to use it in the educational process.
5. Students are more actively and effectively involved with e-ProBotLab when it is taught to solve a problem that interests them. In addition, each scenario prepared for teaching with e-ProBotLab should as far as possible take advantage of the students' previous experiences and ideas.

STEM with e-ProBotLab (Robot Construction)

The term STEM (science, technology, engineering, and mathematics) first appeared in the USA in 2001 and refers to the integrated and unified design of the teaching of the individual fields of science, technology, engineering, and mathematics at all levels of education. It emphasizes the discovery method, the laboratory and research activities, and the interdisciplinary and integrated approach to the objects it deals with (reference). The e-ProBotLab robotic platform can be integrated into this framework since it enables the cross-referencing of various objects through the redesign of the robotic device, given its openness. In particular, the platform can support educational scenarios with primary-, secondary-, and/or high-school students in a variety of subjects.

Electronics and Programming

The e-ProBotLab platform can support scenarios of circuits and electronics and more specifically for robotic construction from the beginning. Students are able to follow the wiring diagrams in order to create the e-ProBotLab robot. At the same time, because of the openness of the platform, simple projects on introductory concepts of electronics, such as the operation of resistance and the learning of various types of sensors, can be developed. With regard to programming, here elementary school students can learn introductory programming concepts such as those mentioned in the previous section. Older students can work on advanced programming themes by adding new features to the e-ProBotLab robotic platform through the C/C++ programming languages.

Math and Logic

Elementary students can be taught subjects such as geometry fundamentals, such as two-point distance, angle, basic geometric shapes, points, lines, and surfaces.

Engineering

Throughout construction, students can learn engineering concepts such as gears, wheel movements, and distance of the device determination, energy issues, and so on.

Discussion

The e-ProBotLab platform is a framework for programming and robotics learning through practice. It was developed by the ICT Research Group in Education (ICTE Group) of the Department of Education and Preschool Education at the University of Patras. It provides the material part and the programming environment for the creation of automotive robots, as well as the pedagogical framework for integration into the educational process. This context of use can be described as vertebrate. It begins with sequential programming learning concepts by guiding a robotic construction and ends up in the construction of an automotive robot using the Arduino microcontroller (http://www.arduino.cc/) and various other mechanical parts. In other words, it enables the development of programming capacity and the handling of robotic technology while, on the other hand, it favors the interdisciplinary approach of basic scientific fields such as the fields of physics, technology, engineering, and mathematics (science, technology, engineering, and mathematics—STEM). The use of robotic construction favors the essential learning of algorithmic concepts as the student understands the concepts of the algorithm in relation to real device programming. There are many reasons why students should be involved with primary algorithmic concepts from an early age. First of all, the involvement of a child with programming concepts helps to strengthen his logical thinking. At the same time, it helps to strengthen its mathematical background as much of the programming is based on fundamental mathematical concepts and build computational thinking skills. Student engagement with technology includes three complementary aspects: how to use technology, how to handle technology, and how to create technology (Depover, Karsenti, & Komis, 2007). In the case of e-ProBotLab, the emphasis is put on aspects of manipulation and creativity.

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Chapter 22
A Virtual Environment for Training in Culinary Education: Immersion and User Experience

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Introduction

Virtual Environments in Vocational Training

Vocational training intends to prepare students to work in a trade or craft. It is often skill oriented and is based on learning by doing (Mellet-d'Huart, 2009). This means that it involves hands on training that is carried out in a laboratory, workshop, or on the job. This requirement makes vocational training less flexible, costly, and difficult for distance learners. Information and communications technologies (ICT) seem to have the potential to leverage the cost and quality of vocational training (Hsu & Chien, 2015).

ICT in vocational training usually take the form of learning management systems (LMS), instructional videos, simulations, games, and virtual environments (VE). These tools don't have the limitations that are related to traditional face-to-face learning. They can be accessed anytime and anywhere, and because they are user-driven and self-paced, they are more comfortable, flexible, and enjoyable for both the local and distance learner (Brown, Mao, & Chesser, 2013; Cawley, 2011; Mills & Douglas, 2004). In addition, they are cost effective, for both students (less transportation and living costs) and institutions (fewer infrastructure, faculty, administration, supervision) (Brown et al., 2013; Cawley, 2011). Research supports that ICT-based learning has similar learning outcomes to traditional face-to-face approach (Brown et al., 2013).

Maybe the most advanced instances of training ICT are virtual environments. They are computer-generated 3D spaces in which users can navigate freely and interact with objects or other users. These virtual worlds can simulate the context,

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tools, and actions that the trainees need to learn. They are usually used for training in areas that are too dangerous, too expensive, or too unreachable (Freina & Ott, 2015; Mellet-d'Huart, 2009). They are considered powerful tools for the training of a wide range of trainees: from industrial workers and soldiers to pilots, astronauts, and surgeons (Borsci, Lawson, Jha, Burges, & Salanitri, 2016; Mellet-d'Huart, 2009). Training in VEs can aim at acquiring procedural skills or more higher-order skills like abstract reasoning and problem-solving under stress (Borsci et al., 2016; Freina & Ott, 2015). However, VEs can also be used to enhance training even when it is feasible in the real world (Mellet-d'Huart, 2009). They can motivate and excite the learner, and their interactivity allows for more constructivist approaches to learning (Freina & Ott, 2015; Pantelidis, 2009).

Presence is a central concept in VEs, which can be described as "the perceptual illusion of non-mediation" (Lombard & Ditton, 1997), or the phenomenon where a person fails to perceive or acknowledge that a mediated experience is mediated. Presence can be divided into two categories: spatial presence which refers to the "the sense of being physically located somewhere" (IJsselsteijn, Ridder, Freeman, & Avons, 2000) and social presence which refers to "being with others" in a mediated environment (Heeter, 1992). Many factors have been suggested as possibly affecting the sense of presence, including media form factors (immersive technology), content factors, and user characteristics (IJsselsteijn et al., 2000).

Depending on the technology used, VEs can be experienced with various levels or immersion and presence. Until recently immersive technologies were very expensive and thus not widely used. A disadvantage they have is that they can cause a feeling of discomfort to their users due to mismatch between user motion in the real and virtual environment (e.g., user is walking in the VE while standing still in reality). This discomfort is called simulator sickness and is similar to motion sickness, although less severe and of lower incidence. Common symptoms include eyestrain, headaches, dizziness, sweating, disorientation, vertigo, and nausea (Freina & Ott, 2015; Kennedy, Lane, Berbaum, & Lilienthal, 1993; Shaw et al., 2015). Nowadays, commercial products like the Oculus Rift head-mounted display (HMD) offer high immersion at an affordable price while minimizing the effects of simulator sickness (Freina & Ott, 2015). Higher immersion is not always more effective or appropriate for all applications. User experience and economic considerations may indicate desktop virtual reality as more suitable for many learning applications (Mellet-d'Huart, 2009).

Virtual Environments in Culinary Education

Culinary education is a form of vocational training which has been booming in the last years. Many students have entered culinary training because of the positive professional image of chefs created by the media (Hsu & Chien, 2015). Nevertheless, technological adaptation in the field has lagged behind that of other academic topics. However, culinary arts are slowly beginning to adopt ICT as a learning tool

(Brown et al., 2013). Research indicates that both culinary educators and students would like more technology in their curriculum (Hsu & Chien, 2015; Mandabach, Harrington, VanLeeuwen, & Revelas, 2002). Referring to the general field of hospitality education, Liburd and Christensen (2013) and Smith and Walters (2012) reported how Web 2.0 and social media contribute to student preparation, support project-based methods, and activate and engage students in higher tourism education. Virtual learning via 3D and other technologies, as an emerging trend of the field, has been the focus of Huang, Backman, and Backman (2010) who investigated students' attitudes toward virtual learning and Lu and Chen (2011) who studied the experience and potential of online learning at the graduate level.

The most researched ICT intervention in culinary education concerns online training videos (Brown et al., 2013; Hsu & Chien, 2015). There are no studies regarding the design, development, and evaluation of VEs for culinary education.

Literature Review

Because there are no studies regarding VEs in culinary education, the scope of the review was extended to also include other ICT tools in culinary education, as well as studies regarding VEs in vocational and adult education.

Hsu and Chien (2015) compared the performance of 100 high school students of a hospitality program in Taiwan in preparing two dishes (one basic and one advanced). The participants were assigned to two groups: the experimental group was trained using online video demonstrations with subtitles via an LMS, while the control group was trained using traditional face-to-face instruction. Their performance was evaluated by experienced chefs, and the results indicated that the experimental group performed better on both dishes.

In a similar study, Brown et al. (2013) compared the learning outcomes for 390 university students who were enrolled in an introductory cooking course, with two instructional delivery methods: online video and live class demonstration. The results indicated that both delivery methods produced similar student performance levels when individual and team tasks were considered together. However, students taught by the online delivery method had better group performance than students taught by the traditional method. The findings suggest that the online video method is effective in culinary arts education.

Feinstein and Parks (2002) reviewed the literature regarding simulations in the hospitality industry. Their review was targeted mainly to managers and decision-makers in the broader hospitality industry and not to culinary educators.

Hsu, Xiao, and Chen (2017) in their review of the hospitality and tourism education research, which include literature from 2005 to 2014, note that the rapid expansion of e-learning technologies is a major challenge for hospitality education institutions in general and point out that only a few studies in the relevant research area address the use of learning technologies. They also note that 3D technologies have emerged as a "sub-theme" of learning technologies in hospitality education.

Moving on to studies regarding VEs in the broader vocational education, Borsci et al. (2016) compared three training experiences for a car service procedure. Sixty participants were randomly assigned to one of the following: (1) observational training through video instruction, (2) experiential training in a high-immersion CAVE (Cave Automatic Virtual Environment), and (3) experiential training through a portable 3D lower-immersion interactive table. The researchers measured the learning outcomes, usability, and workload of each system. Results showed that virtually trained participants can remember significantly better the correct execution of the steps compared to video-trained trainees. No significant differences were identified between the experiential groups, neither in terms of post-training performances nor in terms of proficiency, despite differences in the interaction devices. This suggests that the more affordable lower-immersion interactive table can be as effective as the more expensive higher-immersion CAVE for the training of car service procedures.

Nordbo, Milne, Calvo, and Allman-Farinelli (2015) explored how VEs can be used to understand more about people's food choices. They created the virtual food court (VFC) to test whether policy-based interventions such as the "sugar tax" and "nutrition labelling" can to promote healthier food choices. Studies about the efficiency of such interventions are difficult in large retail settings. The objective of the study was to assess how accurately the virtual food court (VFC) represents a real food court. The VFC used the Oculus Rift HMD and a gamepad for navigation. Twenty-seven participants were assigned in two conditions: a control with regular food court prices and an experimental condition with taxes on food and beverages. The researchers measured the perceived realism and usability of the environment. Results showed that participants were able to imagine doing their real-life food purchases in the VFC indicating that it is a good research tool for assessing people's food choices.

Shaw et al. (2015) created an exercise video game (excergame) with the aim to increase user motivation for exercise and fitness and reduce obesity levels. They evaluated its effectiveness using two levels of immersion: a standard PC monitor and the Oculus Rift HMD. The Oculus Rift resulted in a slightly higher motivation but no noticeable change in performance. The HMD was most effective for sedentary users.

The use of virtual reality (VR) to develop training programs has spread in the last 20 years, in fact, to a variety of industries including, for example, training application for the mining industry (Filigenzi, Orr, & Ruff, 2000; Van Wyk & De Villiers, 2009), surgery skills (Schmitt, Agarwal, & Prestigiacomo, 2012), pilot training (Bakken, Gould, & Kim, 1992), and others.

The literature review reveals that although VEs with various levels of immersion have been used and evaluated in vocational and adult training with positive results, there are no empirical data reported on the use of VEs for culinary education.

Being a chef is acknowledged as one of the most challenging professions in the hospitality industry. Chefs need to possess technical competencies and skills and culinary experiential learning is very important, since the individual must be both introduced to the relevant knowledge and be given the opportunity to practice these skills in the actual kitchen environment (Zopiatis, 2010). The features of VR that contribute to learning (free navigation, first-person point of view, first-order experiences, natural semantics, size, transduction, reification, autonomy, and presence) (Mikropoulos & Natsis, 2011) allow the design of constructive learning environments. Environments like that can provide the basis for virtual experiential learning and contribute in the process of going from "apprentice" to "journeyman," the development of skills and understanding. Students in culinary education do not have access to professional kitchen infrastructure as often as they need during their education, and virtual reality can provide persistent virtual kitchen environments where students can train in various tasks.

The aim of this study is to make a first attempt to design a VE for culinary education, focused on providing training in recipe learning and cooking procedures, and evaluate it in terms of user experience in different levels of immersion.

Method

The Virtual Environment

The "Virtual Chef" VE for culinary education was designed for the purpose of the study. It is the representation of the actual kitchen in which culinary students of a Private Institute of Vocational Training are trained. This allows for authentic learning in a familiar environment. The users of "Virtual Chef" can practice the execution of 50 recipes by collecting the necessary ingredients, cookware, and utensils and using the appropriate cutting and cooking techniques. The VE incorporates gaming features (objectives, review, feedback) that contribute to better learning and reflection. More specifically, the user has to go through four distinct phases.

The first phase is about game initialization, where the user reads the instructions, inputs their name, chooses the level of difficulty (low or high), and selects a recipe to execute (Fig. 22.1). At the end of this phase, the user is presented with instructions on how to execute the selected recipe.

The second phase is a preparatory phase for the execution of the recipe. Users have to navigate in the virtual kitchen in order to collect the necessary ingredients, cookware, and utensils needed for the recipe from three different locations, the fridge, the dry food cabinet, and the cookware and utensils cabinet (Fig. 22.2). Selection of ingredients, cookware, and utensils is made through a menu. When all the required items have been collected into their inventory, they enter the cooking phase.

As noted, in the first phase the user of the VE can choose between two levels of difficulty to execute the recipe. Low level of difficulty ("Chef" level) and high level of difficulty ("Master Chef" level). At the "Chef" level, the user can read the recipe description and a list with all the ingredients, cookware, and utensils needed for the recipe. The user can consult the recipe any time while in the second phase and is not

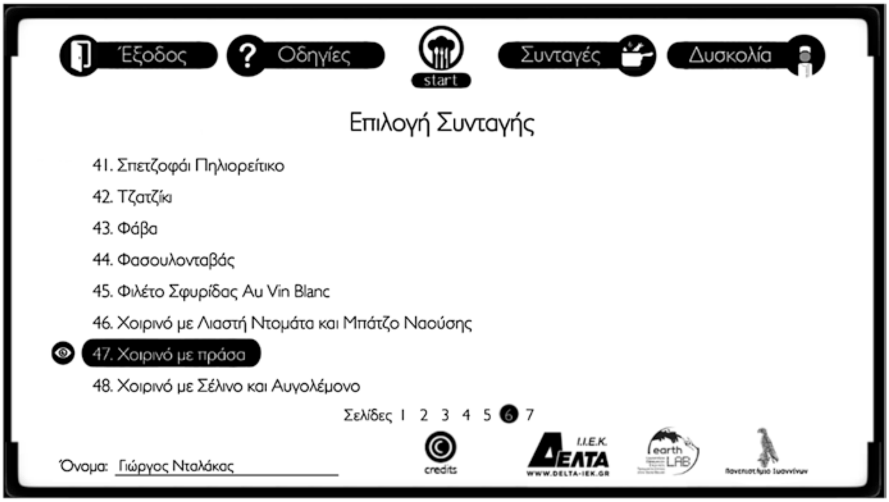

Fig. 22.1 A screenshot from the first phase of the VE. Recipe n. 47 is shown selected

Fig. 22.2 In the virtual kitchen

able to collect ingredients, cookware, and utensils not needed for the recipe, provided with feedback when trying to. When the collection procedure is completed, the VE proceeds automatically to the recipe execution environment. If the user has chosen to play at the "Master Chef" level, they can read the recipe only before they enter the second phase. During the collection of ingredients, cookware, and utensils, the users are able to collect also unnecessary ones. In order to proceed to the

Fig. 22.3 A screenshot from the cooking phase. Icons presenting ingredients, cookware, and utensils shown on the left and icons presenting techniques shown on the right

recipe execution environment (third phase), they have to explicitly choose to do so. In case they have not collected all and only the necessary ingredients, cookware, and utensils, the users are provided with feedback via text message containing information on the number of necessary and unnecessary items they have collected.

In the third phase, the cooking phase, users are presented with a 2D screen with several icons (Fig. 22.3). The left part of the screen contains the icons representing the previously collected ingredients, cookware, and utensils and also standard cooking ingredients (water, oil, pepper, and salt), while the right part of the screen contains the icons representing the available cutting and cooking techniques. The user has to combine the appropriate ingredients, utensils, and techniques in the correct order.

Once all the necessary combinations are completed, the user enters the last phase (Fig. 22.4) where they can review their choices, restart or terminate the application.

The 3D virtual kitchen was modelled with Autodesk Maya και 3D Studio Max. The creation and processing of 2D images and icons was made with Adobe Photoshop. The final VE was created and programmed in Unity3D. Two versions of the virtual environment were developed, one with low immersion and one with high immersion. The low-immersion version (desktop) was presented on a standard LCD monitor and users interacted with the standard keyboard and mouse. The high-immersion version was presented on an Oculus Rift DK2 head-mounted device, with head rotation tracking, a standard game controller, and gaze control (based on the “ProDigital VR No touch GUI” from Unity Asset Store).

Fig. 22.4 The last phase of the VE

Participants

A total of 24 undergraduate and graduate students of a Private Institute of Vocational Training participated in this study. They were specializing in either ICT or culinary arts. Their ages ranged from 18 to 45 years (Mean, 27.92; SD, 8.06), and most of them (87.5%) were males. Participants had no previous experience of the application and were randomly assigned into two groups: desktop (n = 12) and HMD (n = 12). Each group consisted of equal numbers of ICT (n = 6) or culinary arts (n = 6) students.

Instruments

User experience was evaluated by measuring five different user metrics: time to execute a recipe, spatial presence, usability, workload, and simulator sickness.

Time to execute a recipe was measured automatically by the VE in "minutes/seconds". All participants had to select the same recipe.

Presence was measured using the Temple Presence Inventory (TPI), a cross-media, multidimensional, well-validated tool (Lombard, Ditton, & Weinstein, 2009), which is based on seven-point Likert scales.

The usability of a system reflects the ease of learning and using it. It was measured using the system usability scale (SUS), a 10-item questionnaire that measures the overall perceived usability of a system in a range from 0 to 100 (Brooke, 1996). A score over 68–70 indicates that the usability of a system is above average or acceptable (Bangor, Kortum, & Miller, 2009; Nordbo et al., 2015).

User workload was measured using the NASA Task Load Index (TLX). It contains six items that measure mental demand, physical demand, temporal demand, performance, effort, and frustration. The overall TLX score ranges from 0 to 100, with lower scores indicating lower workload (Hart, 2006).

Simulator sickness was measured using the Simulator Sickness Questionnaire (SSQ), a 16-item scale. SSQ provides three subscale scores concerning corresponding symptom clusters (oculomotor, disorientation, and nausea) as well as a total severity score. All scores have zero as their lowest level (no symptoms) and increase with increasing symptoms reported (Kennedy et al., 1993).

Procedure

Participants were brought in a classroom where they were briefly introduced to "Virtual Chef" (Fig. 22.5). Participants of the HMD group received extra instructions on how to wear and use the Oculus Rift, the game pad, and gaze control. Then the participants had to execute the same recipe, going through the four phases of "Virtual Chef." After they completed the recipe, they filled in an online questionnaire containing demographics questions and the scales regarding presence, usability, workload, and simulator sickness.

Fig. 22.5 Participants using the desktop version (L) and the immersive version (R) of "Virtual Chef"

Data Collection and Statistical Tools

The online questionnaire was created and administered with Google Forms. The responses were imported into SPSS 21 for statistical processing. Because the sample was rather small, non-parametric statistical tools were used. More specifically the Mann-Whitney *U* Test was used to detect differences between groups.

Results

Table 22.1 presents the mean time (in minutes:seconds) required for the participants of each group and specialization to execute a specific recipe.

The mean time to complete a recipe was longer in the HMD group (desktop, mean, 09:15; SD, 02:24; HMD, mean,14:53; SD, 03:49), and this difference was statistically significant according to Mann-Whitney *U* test (*Z*, −3.465; *p*, 0.001). The differences between specializations in each group were not significant (desktop, *Z*, −0.641; *p*, 0.522; HMD, *Z*, −0.241; *p*, 0.810).

Table 22.2 presents the mean spatial presence measured with TPI for the participants of each group and specialization.

The mean spatial presence was moderate for both groups (desktop, mean, 4.13; SD, 1.33; HMD, mean, 4.45; SD, 1.22) and did not differ statistically according to Mann-Whitney *U* Test (*Z*, −0.579; *p*, 0.562). The difference between specializations was not significant for the desktop group (*Z*, −1.212; *p*, 0.226) but was significant for the HMD group (*Z*, −2.330; *p*, 0.020).

Table 22.3 presents the mean usability score measured with SUS for the participants of each group and specialization.

The mean usability score was higher in the desktop group (desktop, mean, 80.00; SD, 11.82; HMD, mean, 70.83; SD, 15.35), but this difference was not statistically significant according to Mann-Whitney *U* Test (*Z*, −1.597; *p*, 0.110). The differences between specializations in each group were not significant (desktop, *Z*, −0.964; *p*, 0.335; HMD, *Z*,−0.323; *p*, 0.747).

Table 22.4 presents the mean workload score measured with NASA-TLX for the participants of each group and specialization.

The mean workload score was higher in the desktop group (desktop, mean, 37.22; SD, 11.24; HMD, mean, 29.17; SD, 13.79) but this difference was not statistically significant according to Mann-Whitney *U* Test (*Z*, −1.505; *p*, 0.132). The

Table 22.1 Time to execute a recipe

Interface	Specialization	*N*	Min	Max	Mean	SD
Desktop	ICT	6	06:05	13:57	08:50	02:53
	Culinary	6	07:25	11:57	09:40	02:00
HMD	ICT	6	11:00	22:27	14:38	04:14
	Culinary	6	10:49	21:03	15:08	03:44

Table 22.2 Spatial presence (TPI)

Interface	Specialization	*N*	Min	Max	Mean	SD
Desktop	ICT	6	1.80	6.20	4.50	1.51
	Culinary	6	2.20	5.40	3.77	1.13
HMD	ICT	6	4.00	6.20	5.27	0.78
	Culinary	6	2.40	5.00	3.63	1.04

Table 22.3 Usability (SUS)

Interface	Specialization	*N*	Min	Max	Mean	SD
Desktop	ICT	6	52.50	95.00	81.25	15.23
	Culinary	6	70.00	90.00	78.75	8.48
HMD	ICT	6	45.00	95.00	69.17	20.35
	Culinary	6	60.00	82.50	72.50	9.87

differences between specializations in each group were not significant (desktop, Z, −1.935; p, 0.053; HMD, Z, −0.884; p, 0.377).

Table 22.5 presents the mean simulator sickness score measured with SSQ (total score) for the participants of each group and specialization.

The mean simulator sickness score was much higher in the HMD group (desktop, mean, 5.92; SD, 8.80; HMD, mean, 48.31; SD, 29.16), and this difference was statistically significant according to Mann-Whitney U Test (Z, −3.688; p, 0.000). The differences between specializations in each group were not significant (desktop, Z, −1.879; p, 0.060; HMD, Z, −1.444; p, 0.149).

Discussion and Conclusions

The aim of this study was to design a VE for culinary education and evaluate it in terms of user experience with two different levels of immersion: low (desktop) and high (HMD). Twenty-four students and graduates of a Private Institute of Vocational Training specializing in either ICT or culinary arts participated in this study. Results showed no significant differences in terms of spatial presence, usability, and workload between the two interfaces.

The time to complete a recipe was significantly longer in the HMD group. According to participants' free comments, this could be attributed to the fact that the fonts were too small in the HMD screen and thus difficult to read. This indicates the need to create a different user interface with larger fonts and icons for the HMD version. Another issue that may have delayed HMD users was the gaze control. In order to select an icon, HMD users had to focus their gaze on the icon for 3 s, while desktop users could do the same with an instant mouse click.

Spatial presence was moderate and did not differ between groups. This was rather unexpected since HMD is considered a high-immersion interface that has the potential to produce higher levels of presence. The same and moderate levels of

Table 22.4 Workload (NASA-TLX)

Interface	Specialization	*N*	Min	Max	Mean	SD
Desktop	ICT	6	30.00	50.00	43.61	7.70
	Culinary	6	18.33	48.33	30.83	10.99
HMD	ICT	6	8.33	56.67	33.06	16.98
	Culinary	6	11.67	38.33	25.28	9.68

Table 22.5 Simulator sickness (SSQ)

Interface	Specialization	*N*	Min	Max	Mean	SD
Desktop	ICT	6	0.00	26.18	10.60	10.42
	Culinary	6	0.00	7.48	1.25	3.05
HMD	ICT	6	18.70	74.80	58.59	20.85
	Culinary	6	7.48	100.98	38.02	34.39

presence between groups could be attributed to the fact that only one out of the four phases of the cooking activity involved navigation in the 3D kitchen (collection phase). The other phases (initialization, cooking, and review) involved a standard 2D interface.

Usability was acceptable (score above 70) in both groups, and although the SUS score was considerably higher in the desktop group, the difference was not statistically significant.

The workload was relatively low and did not differ significantly between groups.

The mean total score of Simulator Sickness was significantly higher in the HMD group, a finding that is compatible with literature (Sharples, Cobb, Moody, & Wilson, 2008).

As an overall conclusion, the desktop interface seems more appropriate for the "Virtual Chef" VE. The recipe takes less time to complete, it produces less simulator sickness and of course it is cheap and broadly available. It seems that the extra immersion does not benefit "Virtual Chef" in terms of user experience, maybe because it is not a pure 3D environment but it involves also 2D parts. Even though HMDs can be useful for skills acquisition, including remembering and understanding spatial and visual information related to head movement and visual scanning or observational skills, immersive systems can also distract from the learning task (Jensen & Konradsen, 2017). Immersive systems seem to have an advantage over desktop systems only when the tasks to be carried out involve complex, inherently 3D, and dynamic content (Mikropoulos & Natsis, 2011).

An attempt to objectively evaluate the results of the present study should take into account its limitations. The small number of participants does not allow for wider generalization of the conclusions, and the fact that part of the virtual environment did not include inherently 3D content could have affected the results. But this first report on empirical data on the use of a VE in culinary education constitutes a basis and also a motivation toward further investigation of the potential and added value virtual reality can bring to training modern-day chefs. Studying retention and transferability of learning outcomes that arise from the use of the VE by a larger sample will be a future extension of this study.

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Chapter 23
Using a Web-Based Environment to Enhance Vocational Skills of Students with Autism Spectrum Disorder

Dimitra Tsiopela and Athanassios Jimoyiannis

Introduction

Autism spectrum disorders (ASD) are related to a range of significant impairments in social interaction, communication and intellectual thinking. Individuals with ASD are characterized by repetitive and ritualistic behaviour, they have a limited repertoire of interests and their cognitive development does not follow a homogeneous path (American Psychiatric Association, 2013). Common disabilities encountered by individuals with ASD concern (a) impairments in the areas of attention, memory and information processing, (b) difficulties to shift attention between visual and auditory stimuli and (c) inabilities to manage social relationships and reciprocal interaction, to share enjoyment and interests as well as to understand the feelings expressed by others (Stasolla, Damiani, & Caffò, 2014). Individuals with ASD constitute a very heterogeneous group, manifesting different intellectual levels. Up to 25% of the children with low-functioning autism have additional intellectual and learning disabilities, while many others belonging in the high-functioning end of the spectrum are able to enhance their constructive engagement skills (Palmen, Didden, & Lang, 2012).

Identifying effective interventions and supportive strategies for people with ASD is a continually critical issue for researchers, educators and practitioners (Stasolla et al., 2014). Properly designed instructional interventions, adaptable to individual characteristics, are promising towards helping individuals with ASD to overcome their barriers of adaptive functioning and social interaction, to acquire employment-related skills and to work independently. Among them, computer-assisted intervention (CAI) is considered as an efficient alternative towards designing and implementing developmental interventions and treatment strategies that aim to

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enhance the quality of life for people with ASD and their families as well (Burke, Andersen, Bowen, Howard, & Allen, 2010).

The tremendous advances in digital technologies, over the last decades, have increased the interest of educators and researchers about the potential of information and communication technologies (ICT) to provide education and support to persons with autism. Independent reviews provided systematic analyses of studies involving CAI and showed that digital tools and technologies can reduce behavioural problems, increase responsivity and communication and facilitate the progress of individuals with ASD in social and daily living skills (Knight, McKissick, & Saunders, 2013; Lee, Anderson, & Moore, 2014; Ploog, Scharf, Nelson, & Brooks, 2013; Ramdoss et al., 2011).

Multimedia and Web technologies are promising educational and developmental tools for individuals with ASD, because they are by nature monotropic, rule-governed and predictable and they are suitable to ASD persons' preference for visual stimuli. Therefore, they provide interactive, multimodal and structured spaces that offer very clear boundary and safe error-making conditions while they support individualized learning trajectories. In addition to multimedia applications (Grynszpan, Martin, & Nadel, 2008), various digital technologies have been used, like digital videos (Simpson, Langone, & Ayres, 2004), virtual reality applications (Lahiri, Bekele, Dohrmann, Warren, & Sarkar, 2014), social robots (Kim et al., 2013), mobile devices (Burke et al., 2010; Kagohara et al., 2013) and Web-based environments (da Silva, Gonçalves, Guerreiro, & Silva, 2012).

Literature review identified a wide range of interventions based on digital technologies and ICT environments, which include training in and achievement of skills concerning verbal and language development, arithmetic calculations and conceptual correlations, communication and social interaction, daily living and transition from school to workplace. The majority of ICT-based interventions in children and adults with ASD has been directed, with promising results, to five principal areas of development and adaptive functioning (Ramdoss et al., 2011, 2012 and references therein): (a) language expression and comprehension, (b) communication skills and emotion recognition, (c) social skills, (d) daily-life skills, and (e) work-related skills.

Employability is a major challenge for people with disabilities. It concerns individual training and preparation, as well as policies aiming at their transition to the workplace. Gal, Landes, and Katz (2015) suggested that it is important not only to assess the preferences and the unique abilities of ASD people but also to support them towards developing a range of work-related skills that affect employability, e.g. work habits, independence at work, routines and daily activities and interpersonal skills. However, research on using ICT to support the development of pre-vocational skills of students with autism is rather limited to digital video through mobile devices (Kellems & Morningstar, 2012). The advances in Web technologies offer new Web-based learning tools that empower instructional and treatment interventions in autistic persons by connecting school and home activities and enhancing accessibility through mobile devices.

This chapter reports on an intervention using Pre-Vocational Skills Laboratory (PVS-Lab), a Web-based learning environment, and its effectiveness to enhance pre-vocational and employment skills of young adults with ASD. The intervention consisted of a series of individualized sessions based on PVS-Lab. The participants were five adolescent-young adults, between 17 and 20 years old, which were enrolled in a public special vocational school (SVS) in Greece. The experimental design followed a single-subject approach consisting of an introduction phase followed by an intervention and a transfer phase. A combination of multiple sources of information (e.g. PVS-Lab system log files, psychophysiological data, video and tutors' observation notes) were used from a sequence of individualized sessions. The results indicate a continual improvement in students' performance concerning both correct responses to the learning tasks and improvement in task completion time. In the transfer phase, all the participants performed very well in the grouping and pattern activities, while two students faced difficulties in memorizing and assembling tasks.

Research Method

Aim and Context

This study was designed as a long-term experiment. Therefore, a two-fold aim was set: (a) to identify the different aspects of individual student interaction with PVS-Lab and the specific difficulties they encounter and (b) to measure the impact of this Web-based intervention on autistic students' development of pre-vocational skills, as well as their abilities to transfer these skills to real-life situations.

Both the intervention and the investigation were implemented in a public special vocational school (SVS) in Athens, Greece. The students attending this type of schools have the opportunity to acquire knowledge and skills in a profession area of their choice, and they are trained to use tools and materials. To achieve these objectives, each student attends a different, individualized educational programme (IEP) that meets his/her needs and inclinations. Digital technologies, educational software and the Web play a crucial role in SVS curriculum, since they offer tools that facilitate students' engagement, communication, personalization and interdisciplinarity.

Participants

The participants were five adolescents, four male and one female, enrolled at the SVS above. The students had an official diagnosis of autism and moderate-to-severe intellectual disability. Prior to inclusion in the study, signed parental agreement was obtained. The students were enrolled at this school for more than 2 years; during this period of time, they received lessons on language, math, music, social skills and ICT and were also attending a vocational laboratory of their choice (e.g. gardening, carpentry or tailoring). Before entering this educational programme, all students were familiar with and were using computers, on regular basis, at both school and home. They were able to effectively move the mouse pointer, to use left and right click actions, to turn on and shut down a PC, to run programmes using desktop shortcuts and to adjust the volume of the speakers. Following, the individual profile of each participant is outlined (pseudonyms are used):

Neil is a male, 17 years old, diagnosed with autism and severe intellectual disability. He has very intense attention deficit disorder (ADD), and he is distracted by external stimuli and his own obsessions. He has serious deficiencies in reading and writing and his speech is stereotypical. He has difficulties in communicating and entering social groups, but he has satisfactory eye contact and seeks communication. He is able to follow complex orders and to express his needs verbally, but very often, he is soliloquized and echolalic.

Eric is a male, 20 years old, diagnosed with autism and moderate intellectual disability. He has delayed cognitive and speech development and serious difficulties in communication and social interaction. He shows comparatively better performance in practical than in verbal tests. He has serious writing weaknesses, both at reading/decoding and production level. He has communication and attention deficit and inability of abstract thought. His speech is stereotypical, and he often talks to himself and makes repetitive gestures.

Tom is a male, 17 years old, diagnosed with autism and severe intellectual disability. He has difficulties in communication and emotional transaction. He is usually engaged in stereotyped behaviours and self-injury. He has a 20% hearing loss; occasionally, he gets medication. He has sufficient sense of time and direction, pretty good level of fine motor skills and good level of reading, writing and spelling. He can understand well the written words, and he is able to make mathematical calculations up to 100 quite well.

James is a male, 20 years old, diagnosed with autism and severe intellectual disability. He suffers from epilepsy and is under medication. He is totally cooperative, functional, cheerful and willing to carry out any task. He can follow complex orders and instructions consistently and complete assigned tasks with precision. He has a very good pace of learning and motivation to acquire new skills. Occasionally, he is expressing stress, especially when dealing with unfamiliar situations; however, he does not give up easily. He has serious difficulties in articulation and understanding of speech while he is often giving monosyllabic and stereotypical answers. His initiatives to communicate with tutors and classmates are rare. He writes clearly and quite correctly, while he has a good level of fine motor skills.

Tina is a female, 18 years old, diagnosed with autism, ADD and psycho-emotional distress. She is under medication. She has received training in social level, and she is collaborative in one-one situations. She often shows excessive emotion and fails to comply with the limits. She has well-developed speech and complex thought; she also talks about her feelings unreservedly. Often the flow of her speech is interrupted by personal thoughts and internal discussions. Her general intellectual ability cannot be estimated accurately. Her span of concentration and focus for a given task is short; often she stops, and she is not able to approach a structured activity in a strategic and organized way. Her cognitive skills are below her age and her writing coordination is immature. She has a right-left confusion and deficiencies in space-time identification.

Pre-vocational Skills Laboratory

PVS-Lab is a Web-based environment that simulates a school laboratory. It was designed to support individualized computer-assisted interventions for students with ASD. PVS-Lab is accessible by any device (PC, notebook, tablet or smartphone) just by using a browser. It includes a series of tasks related to pre-vocational skills that adolescents and young adults need to achieve, like attention to details, visual-motor coordination, insistence, self-evaluation, familiarization with objects and working routines, etc. Therefore, PVS-Lab aims to help ASD students develop the skills and self-confidence needed for a successful rehabilitation and a stable transition from school to the working place.

The structure and the main architectural and technological features of PVS-Lab are presented in detail in a previous paper (Tsiopela & Jimoyiannis, 2014). The tool is hosted in a server at the University of Peloponnese, Greece. A database system is used to keep log files of students' performance in terms of student username, operating task and difficulty level, student working time to complete a task and accuracy of students' actions per task. In addition, a multitude of psychophysiological signals (heart rate and skin conductance level) offer important information about students' arousal levels; therefore, tutors can adequately direct their educational interventions towards minimizing the negative effects of students' stress in the learning process.

After registration, the student can access the first room (Fig. 23.1a) which simulates a laboratory with four workbenches. Each bench stands for a different task with various levels of difficulty. The objects placed on the workbench are directly related to each particular task. By clicking on the bench, the students are transferred to the selection screen; thus, they are able to select the difficulty level of the task.

PVS-Lab includes 11 activities simulating common pre-vocational tasks that are important in real-life and working environments. These activities can be divided into five main categories: (a) sorting objects (by letter or number), (b) grouping objects (by size, colour, shape and value), (c) creating patterns, (d) memorizing spatial patterns and (e) assembling objects. The following tasks were used in the intervention and the experiment presented in this paper:

- Task 1: Memorizing spatial patterns
- Task 2: Creating patterns
- Task 3: Grouping by number
- Task 4A, 4B: Grouping by quality
- Task 4C: Grouping by colour
- Task 4D: Grouping by shape
- Task 5: Sorting alphabetically

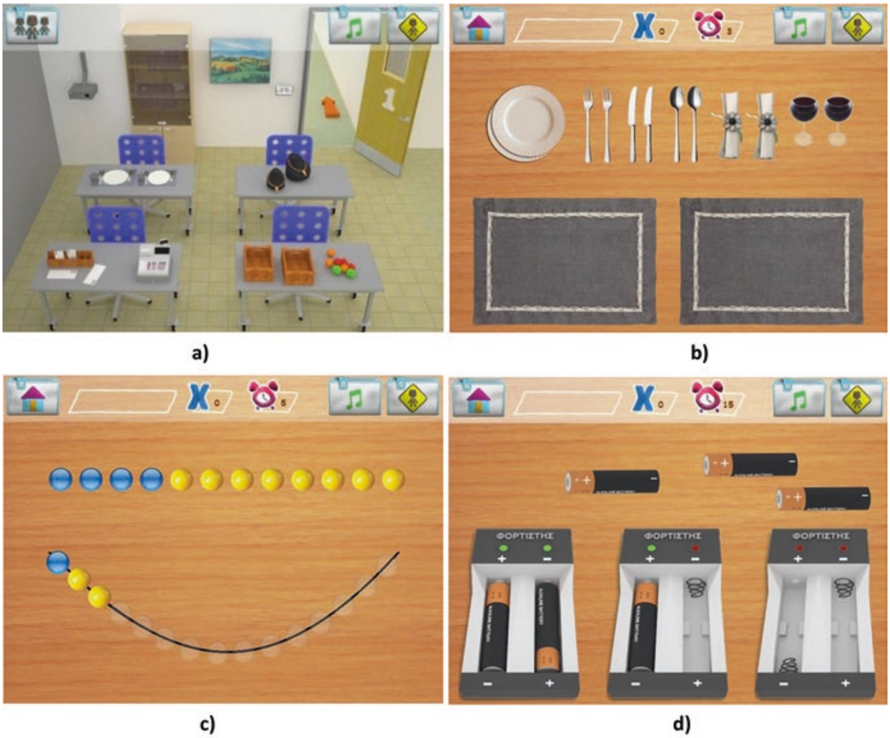

Fig. 23.1 (**a**) PVS-Lab room 1; (**b**) Task1, table setting (level D); (**c**) Task2, creating patterns (level B); (**d**) Task 8, assembling (level B)

- Task 6: Sorting by value
- Task 7A: Grouping by size
- Task 7B: Grouping by length
- Task 8: Assembling objects

Experimental Design

The study was carried out during a period of 2 months. Every student in the sample attended five regularly scheduled personalized sessions. Normally, each intervention session lasted 30 min, and the students were engaged in learning activities using PVS-Lab. In exceptional cases, students wished to terminate earlier; this was immediately respected by the experimenter. The number of trials during each session varied, depending on the student's degree of concentration and the level of task difficulty.

The experimental design followed a single-subject approach, which is considered a powerful research method to observe individual participants' behaviour and changes on a day-to-day basis (Barlow, Nock, & Hersen, 2009; Cohen, Manion, & Morrison, 2007). It consisted of an *introduction* and an *intervention phase*, followed by a *transfer phase*, implemented 2 weeks after the end of intervention phase.

Introduction This was the introductory session aiming at student preparation for the intervention sessions. During the first session, the experimenter explained the task goal and offered guidance to the participants throughout the whole process. The students received encouragement, reinforcement and support in order to get familiar with PVS-Lab interface and be able to implement the tasks included in a proper and efficient way. In most cases, the students were able to successfully use the Web-based tool and to carry out the first tasks through personal inquiry and experimentation. They also received guidance and support to proceed to the tasks of higher difficulty level.

Intervention This phase included four independent sessions conducted over 4 weeks. At first, every student was encouraged to move gradually from the lower to the upper level of task difficulty. They usually followed the predefined task order in PVS-Lab; however, students were free to choose the task level they preferred. During the second session, and afterwards, guidance was offered only when it was necessary, i.e. when the student had serious difficulties or he/she was unable to complete or skip a particular task. Initially, the experimenter offered approval and encouragement; she was gradually fading out and supervised student's activity without intervening. In the final session, therefore, most students were able to work autonomously. The students with excellent scores were free to proceed directly to the highest difficulty level. In cases that they faced at difficulties, they were guided to go back and gradually increase the difficulty level.

Transfer Two weeks after completing the intervention sessions, a last transfer-assessment session was designed with the aim to investigate students' retention and the transferability of pre-vocational skills from the Web-based simulation environment to real-life situations. The students were asked to carry out the following PVS-Lab tasks using real objects:

- Task 1D: Memorizing spatial patterns
- Task 2A, 2B, 2C, 2D: Pattern creation
- Task 8A, 8B: Assembling objects

Four data sources along the PVS-Lab-aided sessions were used in our analysis in a complimentary manner (Tsiopela & Jimoyiannis, 2017): (a) log files from PVS-Lab system database, (b) students' psychophysiological signal data (skin conductance level and heart rate), (c) video recordings of students' actions and comments and (d) observation protocols of students' activities on PVS-Lab.

Results

Students' Performance in Memorizing Spatial Patterns

The results of students' performance in spatial patterns (Task 1) are used as an indicative example of our analysis in this intervention. The aim of Task 1 is to promote students' skills and ability to set a table for two people. In difficulty level A, three types of objects (plate, knife and fork) were given to the students, while in level B, they had six objects to set (plate, knife, fork, spoon, glass, napkin). In order to help students' efforts towards correct choices, an outline of the expected positions of the objects on the computer screen was included. In levels C and D, the participants were engaged in the same two tasks (with three and six objects, respectively) without any indication of the correct positions.

Figure 23.2 shows students' performance in students in Tasks 1B and 1D with six objects as well as their evolution in the successive sessions. The vertical dashed lines indicate the successive sessions of the experimental intervention. It is quite evident that memorizing a spatial pattern was a difficult task for the majority of the students. The strong fluctuation of their incorrect responses indicates that students' development on this particular task was not continually or systematically evolving. It seems that it was easier for them to remember the correct positions of the three objects; however, they had serious difficulties in memorizing the positions of six.

In some cases, the number of wrong responses was increasing in the next session of the intervention. This means that the students faced at difficulties in recalling the correct positions of the objects from the previous session. They showed significant improvement when they firstly completed Level B, which includes hints of the correct positions and them continuing with Level D. Despite their difficulties in the intervention sessions, three participants were able to successfully repeat this task, with no mistake at all, in the transfer phase using real objects.

Students' Overall Performance

All participants were able to carry out simple and repetitive tasks using PVS-Lab. They were able to successfully memorize spatial patterns and repeat patterns, to group, sort and assemble real objects. Comparing the results of the first and the last intervention sessions, a significant improvement in students' performance was apparent. In the transfer phase, the students were able to apply the skills they acquired into a real-life environment and implement the tasks with real objects. All students performed well in the grouping tasks of various criteria (number, quality, colour, shape, size and length) and sorting and pattern repetition tasks. In one task, however, three students still had difficulties. It appeared that the tasks requiring memorization of spatial patterns (Task 1 for Tom and Tina) and assembling objects

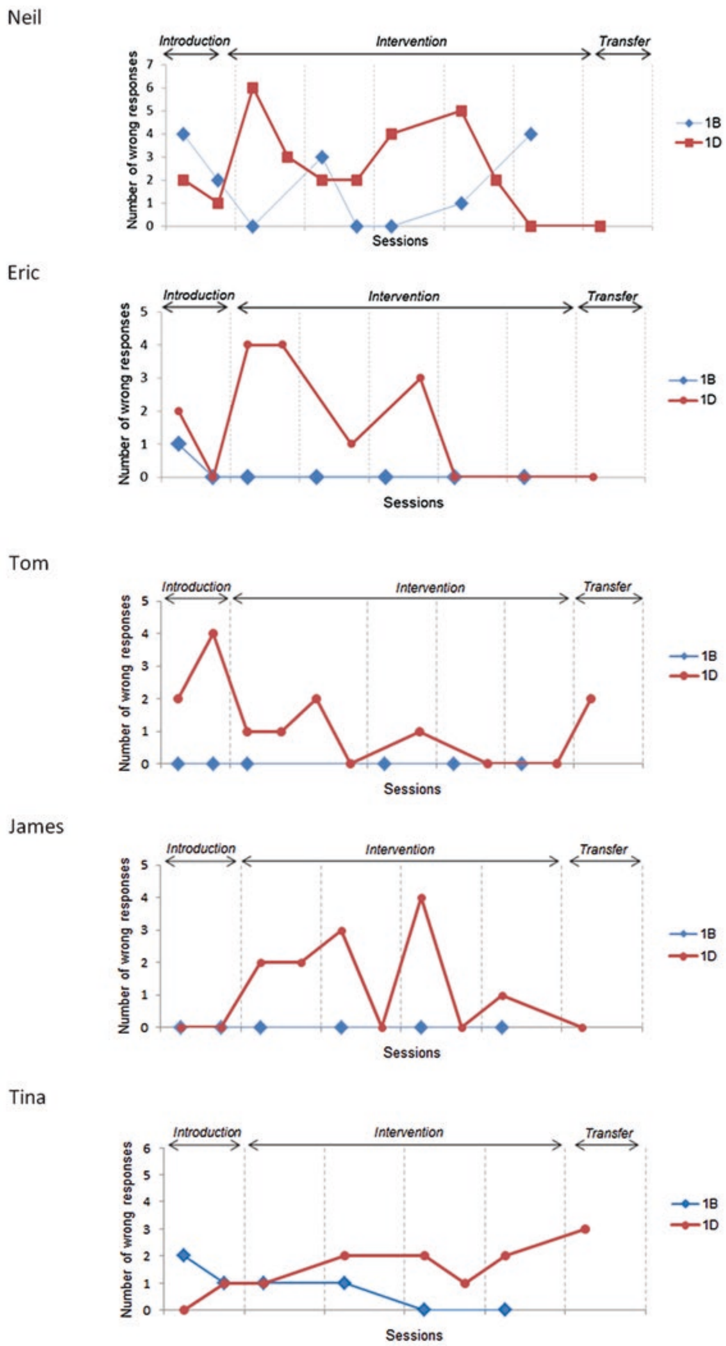

Fig. 23.2 Students' performance along introduction, intervention and transfer phases for Task 1 (B: with indications, D: without indications of the correct positions)

(Task 8 for Eric) were difficult and demanding for those participants. Following, a detailed description of individual performance is outlined for each participant.

Neil In the introductory session, Neil was able, just by following tutor's instructions, to carry out successfully five tasks in PVS-Lab related to grouping tasks, namely, Tasks 3A and 3B (grouping by number), Tasks 4A and 4B (grouping by quality), Task 4C (colour), Task 4D (shape) and Task 7B (length). During the intervention sessions, Neil was able to keep his performance high, in terms of accuracy, without needing further guidance from the experimenter. In addition, a mean reduction of the task completion time up to 17% was recorded. In the introductory session, Neil faced difficulties in six tasks, namely, Task 1 (memorizing spatial patterns), Task 2 (repeating patterns), Task 5 (sorting alphabetically), Task 6 (sorting by value), Task 7A (grouping by size) and Task 8 (assembling). At the end of the intervention period, he was able to carry out successfully all the activities in PVS-Lab.

Eric In the introductory session, Eric was able to successfully carry out eight tasks, namely, Tasks 2A, 2B and 2C (repeating patterns), Tasks 3A and 3B (grouping by number), Tasks 4A and 4B (grouping by quality), Task 4C (colour), Task 4D (shape), Task 6 (value) and Task 7B (length) and Task 5 (sorting alphabetically). During the intervention sessions, he exhibited a continuous improvement and kept his performance high in terms of accuracy; he was able to work independently, without further guidance from the experimenter. The reduction of the task completion mean time for the eight tasks was up to 16%. In the introductory session, Eric faced difficulties in Task 1 (memorizing spatial patterns), Task 7A (grouping by size), Task 8 (assembling) and Task 2D (the highest difficulty level of pattern repetition). At the end of the intervention period, Eric was able to successfully implement all the activities except assembling (Task 8).

Tom Tom performed well in the introductory session, in the majority of the tasks, except Task 1 (memorizing spatial patterns), Task 2B (repeating patterns) and Task 8 (assembling). During the intervention period, he gradually improved his scores in these three tasks, and finally, he was able to complete them correctly. At the same time, he kept his performance high in terms of accuracy in the other tasks; he also achieved 11% reduction regarding the mean completion time. At the end of the intervention period, Tom was able to work independently, without any guidance from the experimenter.

James Similar was James's performance. In the introductory session, he performed well in all PVS-Lab activities with the exception of the two memory demanding tasks, namely, Task 1 (memorizing spatial patterns) and Task 8 (assembling). During the intervention period, he was continually evolving, and finally, he was able to successfully complete these two tasks. He kept his performance high in terms of accuracy and independent work. He also achieved a significant reduction of 23% in relation to the mean time needed to complete the other nine tasks.

Tina In the introductory session, Tina was able, just by following tutor's instructions, to successfully carry out two tasks of pattern repetition (Tasks 2A, 2C) and five grouping activities: grouping by quality (Tasks 4A, 4B), colour (Task 4C), shape (Task 4D), value (Task 6) and length (Task 7B). During the intervention period, she kept her performance high in terms of accuracy. Tina achieved a reduction level of 9% regarding the mean time needed for task completion. At the beginning of the intervention phase, she faced difficulties in six activities: Task 1 (memorizing spatial patterns), Task 2B and 2D (repeating patterns), Task 3 (grouping by number), Task 7A (grouping by size), Task 5 (sorting alphabetically) and Task 8 (assembling). During the intervention phase, she gradually improved her scores in terms of accuracy. In the last intervention session, she was able to complete successfully all the tasks except Task 1 (memorizing spatial patterns).

To achieve an overall, comparative view of the students' performance across the PVS-Lab tasks, we have calculated the mean response time per task object (i.e. the mean duration for each drag and drop action) in the various tasks. Data concerning the trial of the participant's best performance were used (minimum task duration with zero or one wrong response). Figure 23.3 presents comparatively the students' performance along the various tasks in the intervention.

The results in Fig. 23.3 offer a significant indicator regarding the difficulty of each specific task included in PVS-Lab. In addition, they provided evidence that the participants were inclined to the grouping, sorting and pattern activities (Tasks 2, 3, 4, 5, 6 and 7); they exhibited a very good performance with minimal support from the tutor. In terms of their response time, Neil, Eric, Tom and James were able to effectively complete the tasks within a mean response time per object lower than 3 s. However, they generally needed more time to respond to the sorting, memorizing and assembling tasks (Task 1, Task 5 and Task 8), thus confirming existing research findings about the difficulties associated with poor spatial working memory when ASD persons use complex visual information (Schuh & Eigsti, 2012;

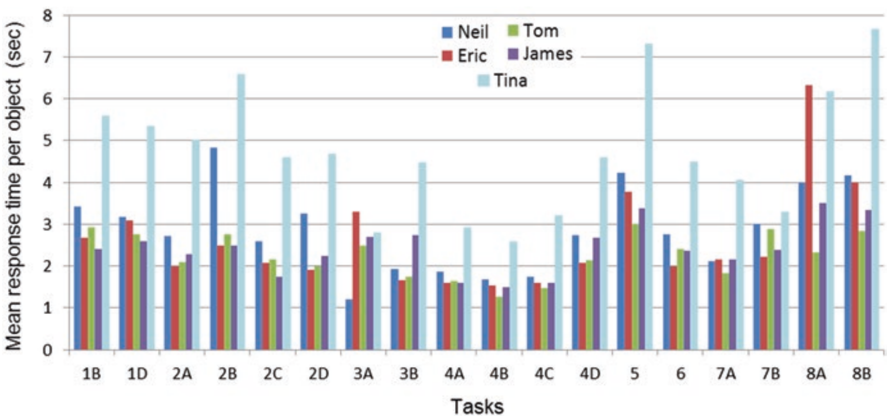

Fig. 23.3 Students' mean response time per object in the PVS-Lab tasks

Williams, Goldstein, & Minshew, 2006). Nevertheless, they were generally able to reproduce spatial patterns if previously they were given an example of the correct positioning.

Tina, on the other hand, was significantly late; she approximately needed a mean time twice longer, than the other participants, to complete a particular task. We can assume that Tina's delay is related to her intense ADD. The results indicate that more sessions were necessary in relation to memorizing, sorting, repetition of patterns and assembling activities, in order to achieve the expected level of pre-vocational skills.

Harnessing in combination the information extracted from the system log files, the researcher's observation field notes and the video recordings of students' interaction with PVS-Lab tasks, it appeared that all students were able to use the system and engage into the activities included. PVS-Lab was a friendly, attractive and enjoyable learning environment to them. The participants were willing to be engaged in this intervention, and they were able, quite soon, to autonomously use PVS-Lab and carry out the tasks assigned by the tutor.

It seems that integrating many different activities of various goals and difficulty levels turned out to be particularly useful, since it offered to the participants a range of opportunities to switch to a different or an easier task, especially in the cases of lassitude or disappointment feelings. The main conclusion, therefore, is that properly designed Web-based environments offer enhanced opportunities as alternative vocational education tools towards preparing and supporting individuals with autism to familiarize with objects, materials, commands and procedures, before starting their transition from school to work.

Discussion and Conclusions

The present study reported on the effectiveness of a Web-based learning environment to enhance pre-vocational and employment skills in young people with autism enrolled in a special vocational school. This long-term intervention consisted of a series of individualized sessions, based on PVS-Laboratory, which was followed by a transfer phase. The results showed that the students responded positively and were willing to interact with the Web-based environment. After the first session, they got familiar with the system and were able to use the PVS-Lab autonomously in order to implement the tasks assigned by the tutor. All the students in the sample performed very well in the PVS-Lab tasks. In many cases, they were able to successfully execute the tasks with minor tutor guidance. The participants demonstrated a continuous and substantial improvement in terms of response accuracy and task completion time, along the timeline of the intervention. However, in some cases, students exhibited fluctuations in their performance which indicate their inability to recall visual and spatial information from a previous session.

All of the five participants in this study demonstrated an inclination towards grouping and pattern repetition tasks; they were able to carry out the tasks with minimum practice and guidance. Four of them were also able to successfully carry out the assembling tasks, at the end of the training period. An important finding is that the students perform better in tasks with low memory requirements. Two students faced difficulties in the tasks that required memorization (Task 1 and Task 8), confirming existing research results with regard to ASD individuals' (a) working memory impairments across visuospatial tasks and (b) flaws in recognition, spatial and working memory (Schuh & Eigsti, 2012; Williams et al., 2006; Williams, Boucher, Lind, & Jarrold, 2013). In the transfer phase, all the participants performed very well in the grouping and pattern activities, while two students retained their difficulties in the memorizing and assembling tasks. Although they were able to carry out Task 1B, which requires students' ability to memorize the positions of three objects, only three participants were able to carry out the same task with six objects.

Therefore, findings from this study expand current research base concerning digital video and mobile devices (Burke et al., 2010; Cihak, Smith, Cornett, & Coleman, 2012; Kellems & Morningstar, 2012) for teaching vocational skills in students with autism and offering assistance in the workplace. In addition, they support the idea that Web-based environments can be effective tools to design appropriate interventions supporting people with autism to acquire pre-vocational skills and promote their transition from school to the workplace.

In addition, this multilevel study showed that collecting and analysing multiple source data (e.g. system log files, video of students' actions and observation notes) can offer valuable information about individuals' inclinations, preferences, barriers and feelings. Therefore, by combining data from various sources, we can assess students' performance and, moreover, construct a holistic view of each individual student, e.g. outline their individual learning profile, identify various emotional or environmental factors that affect their performance or behaviour, etc.

Educators, designers and practitioners working with ASD could harness the affordances of PVS-Lab in order to formulate appropriate individualized educational programmes for adolescents and young adults with autism as well as to prepare their transition from school to work. Secondly, they could adapt their instructional interventions and modify students' long-term individualized programmes in order to minimize distractions and negative behaviours. In addition, capturing and analysing observation and psychophysiological data over time provide valuable evidence of ASD students' progress and offer critical information to the tutor in order to evaluate and monitor the effectiveness of his/her interventions.

Investigating and studying what types of practices and interventions are effective with ASD persons are important not only for young adults with ASD but also for their families, carers, possible employers and the society in general. This paper has the ambition to contribute to an increased understanding of how to integrate Web-based environments in treatment programmes in order to support individuals with autism towards developing pre-vocational and employment skills. The promising outcomes of this particular experiment could not be generalized, since they rely on five individuals. In addition, the unique characteristics of each participant and the individualized nature of this intervention suggest that we need to take these results with caution.

Therefore, despite that data from the tasks analysed indicated that the students were able to maintain the acquired pre-vocational skills, further research is needed to determine if these promising outcomes concern and the other tasks included PVS-Lab. The basic questions that remain open to be addressed for future research concern (a) extending the current research procedure in other samples and participants with autism, (b) replicating the investigation in other treatment contexts (e.g. PVS-Lab offers enhanced opportunities for joined tutor-parent engagement with the aim to guide and support rehabilitation of ASD students), (c) including new tasks of enhanced difficulty in the new version of PVS-lab using different objects and daily-life activities with regard to sorting, memorizing and assembling and (d) using a mobile version of PVS-Lab, including the same or similar tasks, in order to support guidance and motivation of ASD persons in the workplace.

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