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Research on E-Learning and ICT in Education

Technological, Pedagogical and Instructional Perspectives

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Contents

Continuance Intention to Use Mobile Learning in Terms of Motivation and Technology Acceptance

Stavros A. Nikou and Anastasios A. Economides

1 Introduction

Mobile learning, defined as ‘learning across multiple contexts, through social and context interactions, using personal electronic devices’ (Crompton 2013), is a promising educational practise with significant potential (Johnson et al. 2014). Mobile technologies provide new and enhanced learning opportunities, such as personalization and adaptivity, context-awareness and ubiquity, interactivity, communication and collaboration among learners, and seamless bridging between contexts in both formal and informal learning (Sung et al. 2016; West and Vosloo 2013).

Current research in mobile learning primarily focuses on the following: (i) the effects of integrating mobile devices with teaching and learning on students’ learning performance (Sung et al. 2016), (ii) the motivational impact of mobile learning (Hwang and Wu 2014) and (iii) the factors that affect the acceptance of mobile devices into teaching and learning (Nikou and Economides 2018). Researchers also have tried to combine technology acceptance with motivation theories in order to explain and predict behavioural intention to use mobile learning (Nikou and Economides 2017a). Many scholars agree that initial acceptance of any information technology is not enough and, therefore, they suggest that the continuance intention towards using a technology should be used as a success criterion instead (Bhattacherjee and Barfar 2011; Bhattacherjee 2001). In consumer behaviour literature, the Expectation-Confirmation Theory (ECT) suggests

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that satisfaction is the most important variable regarding continuance use of a product or a service (Oliver 1980). In Information Systems, the post-acceptance Expectation-Confirmation Model (ECM) also suggests that user satisfaction determines continuance intention to use information technologies (Bhattacherjee 2001).

Despite the importance of the post acceptance continuous intention towards using an information technology, not many studies exist that focus on the continuation intention to use mobile learning (Rahman et al. 2017). A study by Chang et al. (2013) on the investigation of the continuance intention to use an English mobile learning system found that perceived usefulness had a greater impact on continuance intention than perceived playfulness. Ooi et al. (2018) investigated several social and mobile-related factors that influence the continuous intention to use mobile social learning platforms. Similarly, Joo et al. (2017) found that perceived usefulness and satisfaction affected continuance intention to use digital textbooks. Scholars agree that the topic of the continuance intention to use information technology needs further investigation (Nabavi et al. 2016). While many researchers have highlighted the importance of the continuance intention to use as a post-adoption behaviour (Rahman et al. 2017), to the best of our knowledge, no studies exist on the continuance intention to use mobile learning.

The current study aims to fill the gap in the existing literature regarding the continuance intention to use mobile learning. The study is part of a larger project that aims to further instigate the factors that influence satisfaction and continuance intention towards using mobile learning in the context of secondary science education. Moreover, the study employs constructs from both the Self-Determination Theory of motivation (Deci and Ryan 2002) and the Technology Acceptance Model (Davis 1989). The study is organised as follows. A background on the Technology Acceptance Model and the Self Determination Theory of motivation is presented first. The conceptual model with the hypothesis follows. The methodology section follows with the participants, the instruments used and the procedure. Data analysis and results are next. The study closes with the discussion and conclusions section along with the limitations and future research.

2 Background

2.1 Technology Acceptance Model (TAM)

Technology Acceptance Model (TAM) is one well-known model that addresses the issue of how information technology is accepted by users (Davis 1989). Basic constructs of the model are the perceived usefulness (the degree to which a person believes that using a particular system will enhance his/her job performance) and the perceived ease of use (the degree to which a person believes that using the system would be free of effort). According to the model, perceived usefulness and perceived ease of use are the two key determinants that influence the attitudes of users toward using information technology which in turn affects the behavioural intention to use it (Davis 1989). Explaining and predicting technology system adoption is very important because user acceptance is a critical factor for the successful implementation of any information system. A large number of variables (e.g. facilitating conditions, subjective norm, etc.) have been added that significantly affects information system acceptance (Sumak et al. 2011).

While the predictive power of TAM is indisputable in productivity-oriented (or utilitarian) systems, the impact of intrinsic motivation is usually underestimated in pleasure-(or hedonic) oriented systems (van der Heijden 2004). Therefore, researchers have developed technology acceptance models that integrate motivation constructs as well. Since the early days, Venkatesh (2000) introduced intrinsic motivation (through playfulness) that influences perceived ease of use and system acceptance. The importance of integrating motivational factors on the intention to use or continue using e-learning systems have been highlighted from previous research (Pedrotti and Nistor 2016). In the context of e-learning and mobile learning respectively, Roca and Gagn (2008) and Nikou and Economides (2017a, b) have extended TAM by adding perceived autonomy support, perceived competence and perceived relatedness from the Self-Determination Theory (Deci and Ryan 2002).

2.2 Self Determination Theory (SDT) of Motivation

The Self Determination Theory of motivation (Deci and Ryan 2002) emphasises on intrinsic motivation, the type of motivation that leads to a behaviour that is inherently interesting and pleasant. The theory states that intrinsic motivation is supported when the three basic human psychological needs of autonomy, competency and relatedness are satisfied. Literature refers to the intrinsic motivation as autonomous motivation (versus controlled or external motivation) that leads to a self-determined behaviour. Self-Determination Theory (SDT) of motivation (Ryan and Deci 2000, 2020) is a theory of motivation that defines the following types of motivation: external regulation, introjected regulation, identified regulation and integrated regulation. However, the main two motivation types are the extrinsic motivation (the type of motivation that is built upon external rewards or punishments) and the intrinsic motivation (the type of motivation that leads to a behaviour that is inherently interesting and pleasant). The literature refers to intrinsic motivation as autonomous motivation (versus controlled or external motivation) that leads to a self-determined behaviour.

SDT argues that intrinsic motivation is supported when the three basic and universal human psychological needs of autonomy, competency and relatedness are satisfied (Niemiec and Ryan 2009; Deci and Ryan 2002). Autonomy refers to the desire of people to regulate and self-control their own behaviour. Competence refers to the desire of being effective and sufficient when performing an activity. Relatedness refers to the desire of people to feel connected and associated with others. SDT has been successfully applied in e-learning (Hartnett 2015) and mobile learning as well (Nikou and Economides 2017a). Autonomous motivation found to significantly influence students' decision to use Massive Open Online Courses (MOOCs) (Zhou 2016).

The integration of SDT constructs in the Technology Acceptance model and making use of both extrinsic (perceived usefulness and ease of use) and intrinsic (perceived enjoyment) motivators were successful in exploring and predicting behavioural intention to use. However, the construct of continuous intention to use information technology needs to be further investigated. Sørebø et al. (2009), in their study on teachers' intention to continue use e-learning, found that the basic SDT psychological needs and intrinsic motivation can predict teachers' continuous intention to use. However, not many studies exist that integrate constructs of SDT and TAM in exploring and predicting continuance intention to use information technology. The current study is aiming at predicting and explaining satisfaction and continuance intention to use mobile learning using the construct of autonomy from the SDT and the construct of perceived ease of use of the TAM.

3 Conceptual Framework and Hypothesis

The proposed conceptual framework combines constructs from Self-Determination Theory (Deci and Ryan 2002) and the Technology Acceptance Model (Davis 1989) and is aiming to explain and predict continuance intention to use mobile learning. For that purpose, we have developed the following hypotheses.

3.1 Autonomy (A)

Autonomy is defined as the desire of people to regulate and self-control their own behaviour (Ryan and Deci 2000); the feeling of owning and controlling the initiative of an action (Ryan and Deci 2020). In the context of the Self-Determination Theory, academic literature reports that different degrees of autonomy lead to different intrinsic motivation levels (Gagne and Deci 2005). Previous studies investigated the impact of different forms of motivation in various outcomes including satisfaction (Richer et al. 2002). Satisfaction is defined as the degree to which a person feels positive about the activity (Lin et al. 2005). In work environments, researchers provided evidence for the positive impact of autonomous work motivation on job satisfaction (Lam and Gurland 2008). Moreover, using the Self-Determination Theory as a framework, Gillet et al. (2013) found that autonomous motivation is positively related to work satisfaction. Scholars agree that learning tasks that are perceived as autonomy-supportive can trigger higher intrinsic motivation and satisfaction (Standage et al. 2006). Therefore, in the context of mobile learning, we hypothesize that autonomy has a significant effect on satisfaction. When students perceive mobile learning activities as autonomy-supportive then their level of satisfaction by engaging in mobile learning activities can be high. We hypothesize that:

H1. Autonomy (A) has a positive influence on Satisfaction (A).

3.2 Perceived Ease of Use (PEOU)

Perceived ease of use is defined as the degree to which a person believes that using the system would be free of effort (Davis 1989). Users are more likely to use an information system when they feel that it is easy to use. A meta-analysis by Sumak et al. (2011) provides evidence that perceived ease of use is a major factor that influences attitudes towards using e-learning technologies. The same holds for mobile learning as well (Nikou and Economides 2017b; Briz-Ponce et al. 2016; Mac Callum et al. 2014). User intention to use a system implicitly assumes the existence of a confirmation stage (Rogers 1995) that is associated with a high level of satisfaction (Bhattacherjee 2001).

There is a considerable body of research that investigates the factors that influence user satisfaction (Cho et al. 2011). Previous research provided evidence on the significant effect of perceived ease of use on customer and user satisfaction in using mobile technologies. When user perceive the use of mobile technologies as ease to use they achieve higher levels of satisfaction in mobile shopping (Agrebi and Jallais 2015). In the context of e-learning, Roca et al. (2006) showed that perceived ease of use of an e-learning system can positively influence learner satisfaction. Ooi et al. (2018), in their investigation of the continued use of mobile social networks as a platform for learning they found that satisfaction positively influences continuance intention to use social mobile platforms. Amin et al. (2014), also showed that in the context of mobile websites, there is a positive relationship between perceived ease of use and satisfaction. Therefore, in the context of mobile learning, we can also hypothesize that there is a positive effect of perceived ease of use on satisfaction. Therefore:

H2. Perceived Ease of Use (PEOU) has a positive influence on Satisfaction (S).

3.3 Satisfaction (S)

In Information Systems research, users' continuance intention to use is determined primarily by their satisfaction with prior use (Bhattacherjee 2001). The Expectation Confirmation Theory, from the consumer behaviour literature, (Oliver 1980; Dabolkar et al. 2000) argues that satisfaction is the most significant factor that influences continuance intention to use and positively affects repurchase intention.

Fig. 1 The research model

The Expectation-Confirmation Model (Bhattacherjee 2001), from the Information Systems literature, also considers satisfaction as a strong predictor of continuance intention to use an Information System. Moreover, Dysvik and Kuvaas (2008) found that satisfaction is negatively associated with turnover intentions. In the context of e-learning, researchers by combining the Expectation-Confirmation Model (Bhattacherjee 2001) with the Technology Acceptance Model (Davis 1989), provided evidence that continuance intention to use is associated with satisfaction in the context of e-learning. (Lee 2010). Terzis et al. (2013), in their study on continuance acceptance of computer-based assessment through the integration of user's expectations and perceptions, found that confirmed ease of use was the second strongest direct predictor of continuance intention following confirmed playfulness. Ooi et al. (2018), in the context of mobile learning, provided evidence that mobile ease of use influences satisfaction and learners' continuance intention to use. Similar results have been found by Chang et al. (2013) for the impact of perceived ease of use on continuance intention to use English mobile learning system. Therefore, in the mobile learning context, we hypothesize that:

H3. Satisfaction (S) has a positive influence on Continuance Intention to Use (CIU).

Based on the previous hypotheses, we have developed the model shown in Fig. 1, to explain and predict the continuance intention to use mobile learning.

4 Methods

4.1 Participants and Procedures

The participants were 48 students from a science class in a senior-level high school in Europe. All students had relatively limited previous experience in mobile learning since they have been participated in a small number of mobile-based learning activities. During the current study and in the context of a class-project on biodiversity during the spring semester, students participated in a two-hour mobile learning activity in the botanic gardens. The design of the learning activity, in line with the SDT principles (Deci and Ryan 2002), was autonomy-supportive providing optimally challenging tasks (Hartnett 2015), with meaningful choices and options (Reeve and Halusic 2009) and minimum controlling guidance (Wang et al. 2015; Niemiec and Ryan 2009). Indicative tasks for students are to observe and compare different plants based on their distinguishing characteristics, create taxonomies, identify different operations based on plant morphologies and develop their understanding about biodiversity. Students took advantage of the various affordances of the mobile devices to take photos as artefacts, to upload them onto cloud-based storage, to guide themselves in a variety of activities using QR-coding technology, to receive and provide feedback from tutor and peers through class dedicated social media. The mobile-based version of the assessment was developed using the jQuery mobile framework for the user interface and PHP and MySQL for the server backend support. After the intervention, all students completed a questionnaire about their perceived levels of autonomy, perceived ease of use, satisfaction and continuance intention to use.

4.2 Instruments

For the development of the questionnaire, we adopted items from previously validated instruments. For perceived Autonomy (AUT), we adopted three items that correspond to the autonomy construct from the Need Satisfaction scale (Ryan et al. 2006). For Perceived Ease of Use (PEOU), we adopted three items from Davis (1989). For Satisfaction (S), we adopted items from Lin et al. (2005). For Continuance Intention to Use (CIU), we adopted items from Bhattacherjee (2001). Participants answered on a seven-point Likert-scale ranging from 1 (not at all true) to 7 (very true). Appendix presents the 12 items questionnaire used in the study.

5 Data Analysis and Results

Partial Least-Squares (PLS) with Smart PLS 2.0 (Ringle et al. 2005) was used as the analysis technique to predict factors influencing continuance intention to use. Our sample size exceeds the recommended value of 20 e.g.10 times the largest number of independent variables impacting a depended variable (Chin 1998).

5.1 Instrument Validation

Internal consistency, convergent and discriminant validity of the proposed research model are verified in order to ensure the quality of the model. All criteria for convergent validity are satisfied: all factor loadings on their relative construct exceed 0.70, composite reliability of each construct exceeds 0.70 and all average variance

Table 1 Descriptive statistics and results for convergent validity for the measurement model (acceptable threshold values in brackets)

Construct items	Mean (SD)	Factor loading (>0.70)	Cronbach's a (>0.70)	Composite reliability (>0.70)	Average variance extracted (>0.50)
Autonomy (AUT)	5.54 (1.36)		0.859	0.913	0.779
AUT1		0.883			
AUT2		0.922			
AUT3		0.841			
Perceived ease of use	6.06 (1.02)		0.766	0.866	0.687
PEOU1		0.700			
PEOU2		0.939			
PEOU3		0.829			
Satisfaction	5.90 (0.94)		0.815	0.889	0.729
SAT1		0.881			
SAT2		0.813			
SAT3		0.865			
Continuance intention to use	5.68 (1.24)		0.748	0.842	0.645
CIU1		0.841			
CIU2		0.845			
CIU3		0.712			

Table 2 Discriminant validity for the measurement model (values in bold: the square root of the average variance extracted for each construct)

	AUT	PEOU	SAT	CIU
AUT	0.882			
PEOU	0.710	0.828		
SAT	0.439	0.465	0.854	
CIU	0.628	0.631	0.731	0.803

CIU Continuance intention to use, *SAT* Satisfaction, *PEOU* Perceived ease of use, *AUT* Autonomy

extracted (AVE) values range from 0.645 to 0.779 (AVE > 0.50) exceeding the variance due to measurement error for that construct (Table 1). Discriminant validity is also supported since the square root of the average variance extracted (AVE) of a construct is higher than any correlation with another construct (Table 2). Thus, both convergent and discriminant validity for the proposed research model are verified (Hair et al. 2014).

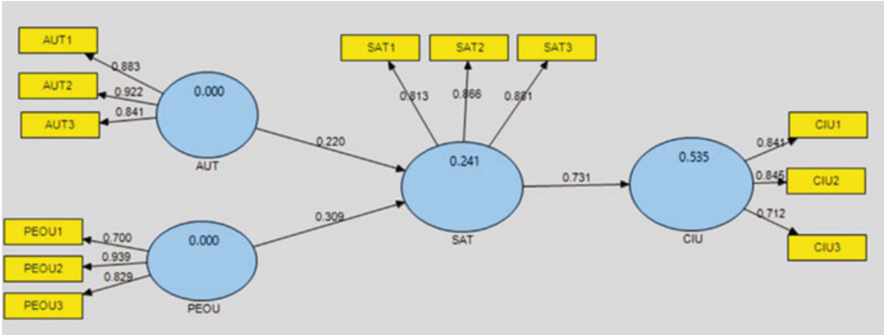

Fig. 2 SEM analysis of the research model

Table 3 Hypothesis testing results

Hypothesis	Path	Path coefficient	Results
H1	Autonomy ➔ Satisfaction	0.220**	Support
H2	Perceived Ease of Use ➔ Satisfaction	0.309**	Support
H3	Satisfaction ➔ Continuance Intention to Use	0.731***	Support

*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$

5.2 *Test of the Structured Model and Hypotheses*

Structural model and hypotheses are supported by the value and the significance (t-values) of path coefficients (the bootstrapping procedure is applied to measure t-values) and the variance measured (R^2) by the antecedent constructs.

Figure 2 summarises the structural model showing the path coefficient for each path and the R^2 for each endogenous variable.

The results from the PLS analysis support all three hypotheses. Autonomy has a direct positive effect (0.220) on Satisfaction. Perceived Ease of Use has a direct positive effect (0.309) on Satisfaction. Satisfaction has a direct positive effect (0.731) on Continuance Intention to Use. Table 3 shows the statistical significance of the relations in the model.

The R^2 value for Continuance Intention to Use is 0.535 and for Satisfaction is 0.241. The model explains 53% of the variance in Continuance Intention to Use. Also, Autonomy and Perceived Ease of Use explain 24% of the variance in Satisfaction, with Perceived Ease of Use to be the most important factor.

The construct of Perceived Ease of Use has the highest mean value (6.06) followed by Satisfaction (5.90). This means that students perceive mobile-based assessment as an easy educational activity and are satisfied with it. Moreover, students report high levels of perceived Autonomy (mean value is 5.54) and also they feel like they are going to continue use mobile learning (mean value is 5.68).

6 Discussions and Conclusions

The current study is part of a larger project to integrate constructs from the Self-Determination Theory of motivation into the Technology Acceptance Model in order to explain and predict intention to use mobile learning and assessment. Studies provided evidence for the predictive and explanatory power of motivation constructs that have already been incorporated into previously developed models (Nikou and Economides 2017a, 2017b). Nikou and Economides (2014a) provided evidence that autonomy, competence and relatedness can explain medical students' attitudes towards using mobile-based assessment and can also predict students' mobile-based assessment adoption. In another study, Nikou and Economides (2014b) found that the SDT constructs significantly affect Economics students' behavioural intention to use mobile-based assessment through attitudes towards use and perceived ease of use. They also developed and validated a framework that builds on the Self-Determination Theory of Motivation and the Technology Acceptance Model (Nikou and Economides 2017a). The framework explains and predicts behavioural intention to use mobile-based assessment based on motivation factors (autonomy, related and competence) and factors related to educational resources and instructional methods used as well as user profile and mobile device features.

All aforementioned studies focus on the behavioural intention to use which is an indicator of the initial acceptance of an Information System. While initial acceptance of an Information System is important, continuance intention to use is vital for its long term viability and success (Bhattacherjee and Barfar 2011; Bhattacherjee 2001). Many researchers have highlighted the importance of the continuance intention to use as a post adoption behaviour (Rahman et al. 2017). Despite the important role of continuance intention in technology usage, a meta-analysis study of satisfaction and continuance intention to use educational technology (Rahman et al. 2017) reveals that not many studies exist that have investigated the implication of continuance intention toward using mobile learning. Previous studies focus on consumer behaviour rather than students continuance intention to use information technologies.

The current study attempts to close this gap in the literature. The study combines constructs from the Self-Determination Theory of Motivation and the Technology Acceptance Model. Study findings revealed that perceived autonomy had a positive impact on student satisfaction. This is in line with previous findings on the role of autonomous motivation in predicting employee's satisfaction (Gillet et al. 2013; Lam and Gurland 2008). Exploring the effect of autonomy on student satisfaction further encourages the development of autonomy-supportive mobile learning activities (Deci and Ryan 2002).

The current study also suggests that perceived ease of use positively influences student satisfaction. This is in line with previous findings on the positive influence of perceived ease of use on satisfaction in the context of an e-learning system (Roca et al. 2006) and in the context of using mobile websites (Amin et al. 2014). Mobile learning users are satisfied when the mobile learning system is easy for them to use.

Another important finding of our study is the positive impact that satisfaction has on the continuance intention to use mobile learning. When students are satisfied with mobile learning activity, they are more likely that they are going to continue use it. According to the post-acceptance expectation-confirmation model (Bhattacherjee 2001), user satisfaction with prior use has a significant effect on post-acceptance continuance intention to use. Our results agree with previous studies that provided evidence on the positive influence of satisfaction on continuance intention to use information technologies (Bhattacherjee and Barfar 2011; Deng et al. 2010) and mobile social networks as a learning platform (Ooi et al. 2018).

The topic of the continuance intention to use information technology has been increasing recently and is an emerging area in information system research (Nabavi et al. 2016). Our study can provide useful guidance to education practitioners to develop mobile learning activities that support learner satisfaction in order to continue using mobile learning. The study is one step forward to understand the factors that support continuance intention to use. However, the main limitations of the current study is its small number of participants and the limited duration of the investigation. More research is needed, with larger samples over longer periods of time in order to further explore the motivational and other factors that significantly affect satisfaction and continuance intention to use. Future study will explore more constructs, with larger sample sizes and in a variety of contexts.

A.1 Appendix

A.1.1 The Questionnaire Used in the Study

Constructs	Items	Questions	Sources
Autonomy	AUT1	I experienced a lot of freedom with the system (mobile learning)	Ryan et al. (2006)
	AUT2	I can find something interesting to do in this system	
	AUT3	The system provides me with interesting options and choices	
Perceived ease of use	PEOU1	My interaction with the system is clear and understandable	Davis (1989)
	PEOU2	It is easy for me to become skilful at using the system	
	PEOU3	I find the system easy to use	
Satisfaction	SAT1	I was satisfied with the activity	Lin et al. (2005)
	SAT2	I was pleased with the activity	
	SAT3	My decision to participate in the activity was a wise one	

(continued)

Constructs	Items	Questions	Sources
Continuance intention to use	CIU1	I intend to continue using the system rather than discontinue its use	Bhattacherjee (2001)
	CIU2	My intentions are to continue using the system than use any alternative means (traditional learning)	
	CIU3	If I could, I would like to discontinue my use of the system	

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The Effect of a Computational Thinking Instructional Intervention on Students' Debugging Proficiency Level and Strategy Use

Ioannis Vourletsis, Panagiotis Politis, and Ilias Karasavvidis

1 Introduction

The term *Computational Thinking*, hereafter CT, was first documented in 1980 by Seymour Papert (1980) in his book *Mindstorms*, referring to a mental skill acquired by children through programming, but did not provide any more explanation. Papert, who had developed the LOGO programming language with Feurzeig and Solomon since the 1970s, argued that programming could be a potential context for the development of mathematical concepts and higher thinking skills, but his theory was not fully accepted (Feurzeig and Papert 2011). CT gained popularity in 2006 when Jeannette Wing defined it as "a universally applicable attitude and skill set everyone, not just computer scientists, would be eager to learn and use" (Wing 2006, p.33). Since then, multiple definitions have been proposed, but it is generally accepted that CT constitutes a set of problem-solving methods that involve "formulating problems and their solutions in a way that can be effectively carried out by an information-processing agent" (Wing 2011), thus a human or a machine, or a combination of both, across a variety of fields (Grover and Pea 2018; ISTE and CSTA 2011; K-12 Computer Science Framework Steering Committee 2016; Shute et al. 2017).

Although various approaches have been proposed for the exposure of students to CT, programming is regarded as primary (Flórez et al. 2017; Kalelioglu et al. 2016; Lockwood and Mooney 2018; Moreno-León et al. 2018). Over the past few decades, some scientists have seen programming as a process of achieving a goal through a planning process, and according to them, every time this plan failed, an

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error occurred (Johnson and Soloway 1984). Other scientists focused on thought processes, attributing the occurrence of errors to limited development of problem-solving strategies (Ginat and Shmallo 2013; Perkins and Martin 1986). Flaws in computer programs are “like natural bugs, they‘re everywhere” (Metzger 2004, p. 1), but while admitting that we expect to encounter errors of various kinds in novice programmers, it is useful to explore the thought processes and strategies of novice developers when producing and correcting errors. This includes focusing on what students think when they produce bugs, since they “learn from their mistakes only when the causes of the faulty mental models causing the errors are understood” (McCauley et al. 2008, p. 68).

This study aims to examine the effect of a CT instructional intervention on students’ ability and use of strategies to find and correct program errors while programming in a visual programming environment. It begins by clarifying the term “testing and debugging” and its relation to CT. Afterward, presents the work of other authors that have focused on students’ errors and strategies to correct bugs while programming, but have not adequately discussed them in the context of CT and primary education. The following section addresses methodology issues, such as the research question and design, the sampling process, and the data collection and analysis methods. The last sections present the findings of the study and their discussion in comparison to the literature review.

2 Testing and Debugging: A Core CT Practice

The process of testing a computer program, including finding and resolving defects or problems within the program code is defined as debugging (Böttcher et al. 2016; CollegeBoard 2017; Ginat and Shmallo 2013; McCauley et al. 2008). According to Csizmadia et al. (2015), debugging is a key feature of every programming activity, entailing a systematic application of testing, tracing, and logical thinking.

CT is a problem-solving methodology (Barr and Stephenson 2011; Wing 2006) for which testing and debugging is considered as fundamental (Adams et al. 2019; Brennan and Resnick 2012; Grover and Pea 2013, 2018). Brennan and Resnick (2012) proposed a three-dimensional CT model (concepts, practices, and perspectives), according to which testing and debugging is included within CT practices. The vast majority of CT frameworks use this model as their base, including the *3D Hybrid CT Framework* by Adams et al. (2019). After conducting an extensive review of the existing CT assessment instruments, Adams et al. organized measured competencies into their framework, and categorized testing and debugging as a CT practice, too (see Table 1). Furthermore, the practice of testing and debugging as a process of detecting and correcting defects is part of any problem-solving process, not only in a computer programming environment (Grover and Pea 2018). Examples include the amount of salt a person tries to add to a dish, or even the corrections of the text messages they send. In this sense, testing and debugging links to other CT components involved in solving a problem, such as the evaluation

Table 1 The *3D Hybrid CT Framework* by Adams et al. (2019, p. 280)

CT concepts	CT practices	CT perspectives
Logic and logical thinking	Problem decomposition	Creation
Algorithms/algorithmic skills and thinking	Testing and debugging	Self-expression
Pattern recognition	Problem-solving	Communication
Abstraction	Organization	Collaboration
Generalization	Planning	Questioning
Evaluation	Modularizing and modeling	Reflection
Automation	Being incremental and iterative	Skill transfer
Data	User interactivity	
Synchronization		

of the computational solution, logical thinking, and the abstraction for isolating and decomposing the problem.

According to Griffin (2016), among the researchers who focus on debugging, some view it as a remedial activity that takes place after the writing of code, while others choose to insert bugs on purpose, and then require the students to explain, find, or fix them. However, testing and debugging in the context of CT practices has received only a small share of researchers' interest compared to other CT components. In their literature review of empirical research in the development of CT through programming, Lye and Koh (2014) found that that 85% of published studies investigated learning outcomes only in terms of CT concepts. More recently, Liu et al. (2017) also highlighted the underrepresentation of CT practices in scientific research, especially testing and debugging. A possible reason is that visual programming environments, which are the main environment used for promoting students' development of CT components, are not primarily designed as contexts to teach debugging techniques. Block-based programming environments, such as Scratch, represent commands with icons (blocks), whose particular shape allows the connection only to specific other blocks, preventing syntax errors (Resnick et al. 2009). As a result, debugging in such environments focuses on correcting the deviation between the observed behavior of the program and the intended one, as opposed to syntactical analysis. Indeed, as in text-based programming environments, programming errors often do not implicate syntax but rather reflect a poor understanding of the underlying concepts involved and/or limited problem-solving skills (Ginat and Shmallo 2013).

3 Related Work

The study of the debugging process as implemented by successful programmers, especially novices, provides useful information about their strategies to trace and correct bugs, and may suggest implications for teaching (McCauley et al. 2008). Vessey (1985) carried out preliminary work for the process of debugging in the

1980s when she applied verbal protocol analysis to the data collected from 16 novice programmers employed by the same organization. She identified a hierarchy of goals, where participants compared the correct and the incorrect output, gained familiarity and control of the program, evaluated it, and eventually made hypotheses about the error and finally repaired it. The first investigations of the debugging process also suggested that as programmers gain experience in debugging, they become capable of recognizing common program errors ("clichés") (Ducassè and Emde 1988).

In the last few years, much more information on the debugging techniques of beginner programmers has become available. According to Miljanovic and Bradbury (2017), code tracing, print statements, divide-and-conquer, and breakpoints are among the most common debugging techniques. Code tracing refers to the reading of the code to find errors, and print statements involve inserting output statements into a program to gain information about its internal status. Divide-and-conquer includes a systematic decomposition of the code into smaller parts to isolate the error, and breakpoints are intentional pauses in the execution of a program to gain information about it. Liu et al. (2017) described the problem-solving behaviors of 6–8 graders in a debugging game. They found out that students applied alternative solutions to face the problems, such as editing wrong parts of code, deleting parts of code without reading them, proceeding random changes, starting with the tedious path when two or more strategies were available, or quashing correctly fixed bugs instead of looking for other errors. Michaeli and Romeike (2019) highlighted the importance of a systematic debugging process, as is usually employed by professionals, consisting of testing the program, detecting errors, formulating hypotheses, verifying, and then refining the code, in an iterative manner until the program is correct.

A key question with much of the literature concerning the practice of debugging is whether students learn debugging strategies via explicit teaching or develop them through debugging experiences. According to Kessler and Anderson (1986), debugging does not derive directly from the ability to write code and therefore eventually needs to be taught. Even in the last few years, some researchers argued that explicit teaching of debugging strategies could be effective. Böttcher et al. (2016) taught 48 first-year students a systematic process of debugging Java programs (see Fig. 1) and discovered that only a few of them employed it. This work also reported a correlation between debugging and nontechnical skills; in particular, they found that students who used the required technical vocabulary correctly also worked more systematically. Michaeli and Romeike (2019) showed that explicit teaching of debugging strategies could significantly improve the skills of 28 students of a year 10 (ages 15 to 16) class, and have a positive effect on their debugging self-efficacy.

On the other hand, many experts, in line with the constructivist pedagogical approach to learning, contend that it is more effective to encourage and support students to discover their own mistakes and correct them. This idea is not a recent one, as Wilson, in 1987, referred to the use of the Socratic method for the support of the debugging process of novice programmers. This technique

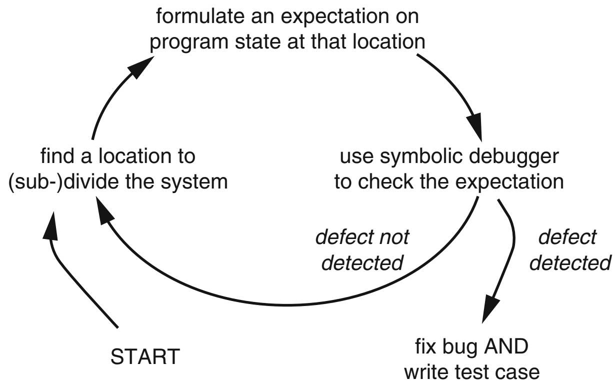

Fig. 1 A systematic debugging process. (Böttcher et al. 2016)

involved the instructor interacting with students individually, leading them to a better understanding of the problem, and eventually to its solution. Chmiel and Loui (2004) demonstrated that students who completed optional debugging exercises needed significantly less time on tracing and removing errors in their programs than those who did not. According to the researchers, formal training in debugging through exercises, logs, reflective notes, and collaborative assignments could be beneficial for the development of the students' debugging skills. Robertson et al. (2004) investigated the proper mechanism for the programmer's support in finding and correcting code errors, showing that negotiated-style interruptions, such as underlining of errors, were more effective than immediate-style ones, such as pop-up windows. They found that frequent breaks in the debugging process were not helpful to the students, presumably because this impeded short-term memory.

Finally, a review of the recent literature shows that researchers have used different activities for the engagement of students in a debugging process. Yoon et al. (2014) introduced an online game with large numbers of players named *DeBugger*, in which students solved programming problems to defeat virtual bugs, and demonstrate a positive effect of the game on students' knowledge about the JAVA programming language and on social interaction during learning. Miljanovic and Bradbury (2017) designed *RoboBug*, a game that is customizable for different programming languages and levels. The game introduced first-year Computer Science students to debugging challenges, with a positive effect on learning outcomes, especially for students with low initial test scores. According to Proctor (2019), the use of interactive storytelling in the context of a computer science course can also lead to the improvement of students' debugging skills. The researcher drew his conclusions after analyzing students' reading, writing, and debugging practices over 4 months of a middle-school course. The use of an educational robotics kit during a training experience in CT skills and social interaction contributed to the development of debugging skills of a primary school class of 46 students in Spain (Caballero-Gonzalez et al. 2019), as well as different embodied instructions in

ScratchJr, a block-based programming environment for young children (Ahn et al. 2017). Furthermore, results from 69 high school students making electronic textile (e-textile) artifacts over 8 weeks as a part of their introductory computer science course showed that the hybrid nature of e-textiles could be a promising context for the development of debugging skills (Jayathirtha et al. 2018; Lui et al. 2017).

4 Method

4.1 Research Questions and Design

This study examines the effect of a CT instructional intervention on students' testing and debugging proficiency level and strategy use. Previous work has focused on testing and debugging proficiency level and strategy use, but their characteristics in the context of a CT instructional intervention in a primary school have not been dealt with in-depth. More specifically, the study addresses the following research questions:

1. What is the effect of a CT instructional intervention on the testing and debugging proficiency level of sixth-grade pupils?
2. What is the effect of a CT instructional intervention on the ability of sixth-grade pupils to employ systematic debugging strategies?

In order to investigate these questions, we used a repeated-measures design protocol, in which we took multiple measures of a dependent variable on matched subjects under different conditions (Salkind 2010). Each pair's testing and debugging proficiency level and debugging strategy that discussed and decided to employ while debugging *Scratch* code were the dependent variables, which we measured under four conditions, corresponding to the four learning units of the instructional intervention (related groups of the independent variable). During repeated-measures designs, the individual differences of the participants are reduced, given that the same participants perform the same tasks or experience the same treatments, but there may be order effects, thus the effect of the order of the conditions or treatments on the participants' behavior.

4.2 Participants and Setting

A total of 43 pairs of sixth-grade students participated in the study. All 86 participants attended primary schools in the Athens metropolitan area during the 2018–2019 school year. We adopted a convenience sampling approach, since the participants were selected based on availability and willingness to take part. During each of the four learning units of our instructional intervention, we measured the

43 pairs' testing and debugging proficiency levels and assessed their debugging strategies. As a result, we made 172 measurements of their testing and debugging proficiency levels and equal assessments of their debugging strategies.

The instructional intervention of this study took place at the schools' ICT rooms, during the regular school hour assigned to Information Technology, for one teaching period per week. The ICT rooms provided the students with a network-connected workstation and the teacher with a portable computer. The first author taught the CT course in collaboration with an ICT teacher.

Throughout this paper, we use the terms *instructional intervention* and *course* interchangeably, referring to the series of teaching periods dedicated to the CT concepts, practices, and attitudes. We should point out, though, that the Greek curriculum for compulsory education does not currently include CT.

4.3 Procedure of Instructional Intervention

During the 28 week-long intervention, the participants worked in pairs (due to limited workstations) in the context of *Scratch*, a block-based visual programming language (Resnick et al. 2009). Students' partners were assigned by the researchers randomly and did not change until the instructional intervention was completed, since the effects of pair programming on students' testing and debugging proficiency level and strategy use fall outside the scope of this paper. The content of the instructional intervention was part of the *Creative Computing Curriculum*, developed by the Creative Computing Lab at the Harvard Graduate School of Education (2014). The guide's activities emphasize the creative aspects of computing, through the creation, remixing, and debugging of computational artifacts, aiming at the students' preparation for the use of the "CT concepts, practices, and perspectives in all aspects of their lives, across disciplines and contexts" (Creative Computing Lab at the Harvard Graduate School of Education 2014, p. 1).

The participants worked for up to approximately 5 h cumulatively for the debugging of *Scratch* code, through debugging challenges in four different learning units (*Exploring, Animations, Stories*, and *Games*). The instructors made an introduction to the debugging challenges at the beginning of each teaching period and then asked the pairs to work on their activities. The instructors then visited each pair to observe the way they were working and to collect data. Finally, the students participated in a plenary session discussion about the approaches they followed in solving the problem. The instructors encouraged the conversation through questions regarding the tasks.

During the introductory unit (*Exploring*), the students familiarized themselves with the computational concept of sequence and the practice of experimentation and repetition. The first debugging challenge involved two characters of *Scratch* programs, called sprites, who were meant to start dancing at the same time after the students had clicked the green flag, which starts all scripts in a project, but instead only the *Scratch* Cat sprite did. The second one involved the *Scratch* Cat starting on the left side of the screen (stage), saying something about being on the left side, gliding to the right side of the stage, and saying something about being on the right side. The program worked the first time the students clicked the green flag, but not again.

In the course of the *Animations* unit, which is arts-related, the students created animation programs, while experimenting with the concepts of loops, events, and parallelism. In the first *Scratch* program to debug, the *Scratch* Cat should have danced while a drumbeat played along with him. However, when the students clicked the green flag, the *Scratch* Cat started to dance, and then stopped, while the drumming continued without him. In the second debugging activity, the program started with the *Happy Birthday* song playing, and while the song was playing, instructions appeared for blowing out the candles. However, the instructions should have appeared after the song playback had finished (Fig. 2).

The next learning unit (*Stories*) focused on media and digital storytelling, as the students gained familiarity with the benefits of reusing and remixing *Scratch* projects. They also developed fluency with CT concepts (events, parallelism) and practices (experimenting and iterating, testing and debugging, reusing and remixing). The first debugging challenge involved the *Scratch* Cat teaching another sprite, Gobo, to meow, and the second challenge teaching him to jump. In neither of the two cases, Gobo did what the *Scratch* Cat asked him to do.

Finally, during the Games unit, the students created and debugged digital games while gaining experience both with CT concepts (conditionals, operators, data) and CT practices (experimenting and iterating, testing and debugging, reusing and remixing, abstracting and modularizing). In the first buggy Scratch program, an inventory list should have been updated every time the Scratch Cat picked up a new item across the stage. Nevertheless, he could only pick up one of them, the

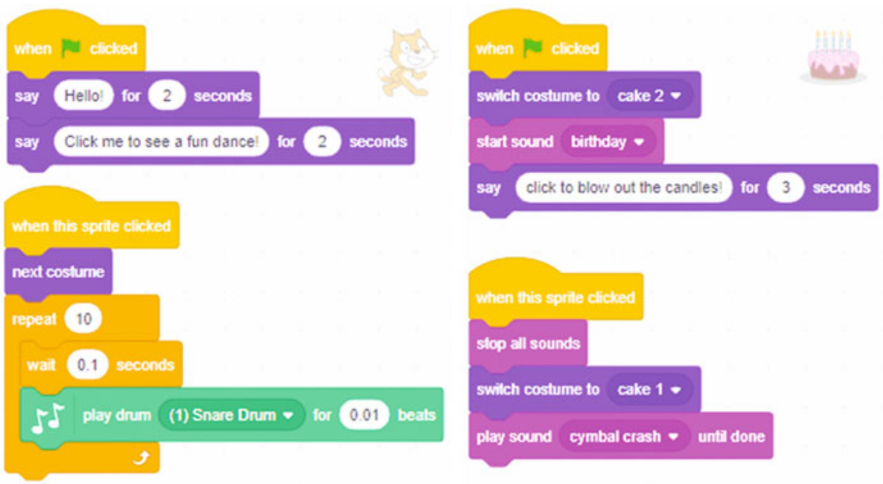

Fig. 2 Debugging challenges in the *Animations* unit

laptop. In the second buggy program, the Scratch Cat was navigating a maze to reach a yellow rectangle, but he could walk through walls, although he should not have done so.

4.4 Data Collection and Analysis

In order to determine the students' testing and debugging proficiency level and strategy employment, we collected data through think-aloud protocols, prompted written descriptions of their actions, semi-structured interviews, screen recordings, and a rubric. When possible, we used data triangulation to combine multiple sources of data and facilitate their validation (Cohen and Manion 2000). During the analysis, we employed both quantitative and qualitative data analysis methods.

In particular, we asked every pair of students to think aloud as they performed the debugging tasks, expressing whatever they saw, processed, performed, and felt (Ericsson and Simon 1984). The analysis of the transcribed data at first focused on finding nouns and noun phrases relevant to the debugging process (referring phrases analysis), then on finding sets of assertions to determine possible relationships between debugging concepts (assertional analysis), and finally on finding overall descriptions of the processes that students used (Fonteyn et al. 1993). The data of the participants' speech let us delve into their cognitive processes and strategies to complete the debugging activities. When necessary, we used semi-structured interviews with the pairs to clarify specific parts of their explanations. Furthermore, after they completed the task, we asked every pair to reflect on their testing and debugging experiences by writing down their responses to four reflection prompts ("What was the problem?", "How did you identify the problem?", "How did you fix the problem?", and "Do you have alternative approaches to fixing the problem?"). Then, we used content analysis (White and Marsh 2006) to extract all the paths the students followed to solve their debugging challenges. Finally, for two pairs of students (approximately only 5% of the total, due to equipment restrictions), we identified patterns of their processes not only through analysis of the aforementioned types of data but also through content analysis of screen recordings taken during the debugging process.

The analysis led to three categories of strategies that were exhaustive, mutually exclusive, and independent. The first category, systematic strategies, refers to the students' employment of an iterative process of testing the program, detecting errors inside it, formulating hypotheses, and refining them until they fixed the bugs. In most cases, the participants began with executing the program, comparing it with the expected result, and then dividing the code into smaller parts. The second category, partially systematic strategies, were employed when students either focused on wrong parts of the code and tried making changes to them according to an original hypothesis, or traced the part that contained the error but tried to repair it by inserting a new one. However, the new code was not suitable for the problem. Finally, we considered that students employed a third category, non-systematic strategies, when they only visually examined the code without making changes, or they tried to create completely new code to perform the programs' expected result, replacing the initial one.

We also used the analyzed data to assess every pair's fluency regarding the computational practice of testing and debugging. The instrument adopted for the assessment was a rubric, which is part of the *Creative Computing Curriculum* (Creative Computing Lab at the Harvard Graduate School of Education 2014). The rubric contains four questions for the students to (a) describe what happened when they ran their projects that was different from what they wanted, (b) describe how they read through their scripts to investigate the cause of the problem, (c) describe how they made changes and tested to see what happened, and (d) describe how they considered other ways to solve a problem. Three statements describe students' actions that manifest low, medium, and high levels of proficiency for each question. After we had defined the criteria, we assigned one point to the low level for each question, two for the medium, and three for the high. We then calculated the mean score of the pairs' proficiency level regarding the CT practice of testing and debugging, resulting in a range that included a minimum of value 1 (*low level*) and a maximum of 3 (*high level*).

We assessed the pairs' proficiency level and strategy use regarding the CT practice of testing and debugging four times corresponding to the four learning units of the course, thus being the four levels of the independent variable. The software application package we used to analyze the data was the *Statistical Package for the Social Sciences* (*SPSS*®). A one-way repeated-measures analysis of variance (ANOVA) was conducted to determine whether there are any statistically significant differences between the means of the debugging proficiency levels between the four learning units (levels of the within-subjects factor) and then all pairwise comparisons (post hoc tests) were performed (Weinfurt 2000). Furthermore, we calculated partial eta squared (partial η^2 or $\eta_p{}^2$), as a measure of the sample effect size, and partial omega squared (partial ω^2 or $\omega_p{}^2$), as a measure of the population effect size (Cohen 1988). As for students' debugging strategies, the use or non-use of each group of strategies served as a dichotomous dependent variable, and we conducted Cochran's *Q* test to determine if there were differences in the variable between the four learning units (Cochran 1950). Pairwise comparisons were performed using multiple McNemar's tests (with a Bonferroni correction). All the necessary assumptions for conducting the tests were met.

5 Results

5.1 Students' Testing and Debugging Proficiency Level

The statistical analysis of the data showed that students' proficiency level of the testing and debugging CT practice (see Table 2) was low or medium across all four

Table 2 Descriptive statistics regarding students' testing and debugging proficiency level

Descriptive statistics			
Learning unit	Mean	Std. Deviation	*N*
Exploring	1.76	0.44	43
Animations	1.93	0.46	43
Stories	1.80	0.51	43
Games	2.02	0.50	43

learning units, since their means hardly reached value 2, assigned to the medium level of the three-level rubric used. In particular, the mean score of the practice in the introductory unit of *Exploring* was the lowest one measured ($M = 1.76$, $SD = 0.44$) and increased in the next unit of the *Animations* ($M = 1.93$, $SD = 0.46$), although still regarded as low. At the end of the learning unit of *Stories* the mean score of the practice was lower ($M = 1.80$, $SD = 0.51$), but at the end of the instructional intervention, after the completion of the *Games* unit, the mean score exceeded value 2, which corresponds to the medium level of proficiency ($M = 2.02$, $SD = 0.50$).

A one-way repeated-measures ANOVA was conducted to determine whether there were statistically significant differences in students' testing and debugging proficiency level over the four learning units of the instructional intervention. There were no outliers and the data were normally distributed, as assessed by inspection of a boxplot and Shapiro-Wilk test ($p > 0.05$), respectively. The assumption of sphericity was not violated, as assessed by Mauchly's test of sphericity, $\chi^2(5) = 2.66$, $p = 0.752$. The learning units of the CT intervention elicited statistically significant changes in students' proficiency level of testing and debugging CT practice, $F(3, 126) = 10.23$, $p < 0.001$, partial $\eta^2 = 0.200$. Therefore, we cannot accept the null hypothesis of equal mean scores regarding the practice across the units.

Post hoc analysis with a Bonferroni adjustment revealed that the mean of the CT practice of testing and debugging was statistically significantly larger in the *Exploring* unit ($M = 1.76$, $SD = 0.44$) as compared to both the *Animations* ($M = -0.17$, 95% CI [−0.31, −0.03], $p = 0.013$) and the *Games* units ($M = -0.26$, 95% CI [−0.41, −0.10], $p < 0.001$). Furthermore, mean performance score for testing and debugging was statistically significantly increased from *Animations* to *Stories* ($M = 0.13$, 95% CI [0.01, 0.26], $p = 0.034$) but decreased from *Stories* to *Games* ($M = -0.22$, 95% CI [−0.37, −0.07], $p = 0.001$). A line graph summarizes the results (see Fig. 3).

5.2 *Students' Testing and Debugging Strategy Use*

The analysis of the collected data indicated that students employed more frequently a partially systematic debugging strategy. In particular, partially systematic debugging approaches appeared 21 times during the *Exploring* unit, a number that corresponds to 48.9% of the 43 strategies recorded in the unit. The second most

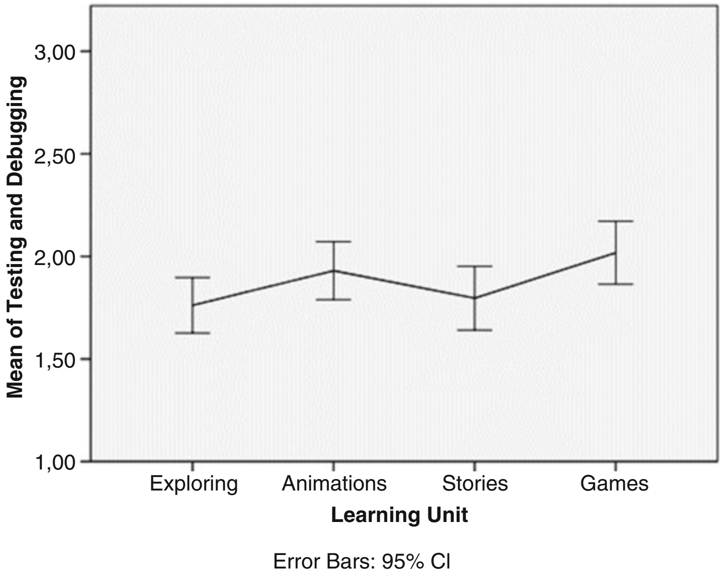

Fig. 3 Line graph of repeated measures regarding testing and debugging across the learning units

employed approach was a non-systematic (17 times or 39.5%), while the least employed one was the systematic one (5 times or 11.6%).

During the debugging of arts-themed projects in the *Animations* learning unit, partially systematic approaches appeared 21 times (48.8% of the unit's strategies) and non-systematic ones had the second-highest frequency of employment (13 times or 30.2%). Systematic approaches were used less (9 times or 21%) in both the *Animations* and the *Stories* units (7 times or 16.3%). When debugging digital stories, students used approaches categorized as non-systematic 16 times, corresponding to 37.2% of the unit's strategies, and partially systematic approaches 20 times (46.5%).

Nevertheless, when the participants tested and debugged game programs, they employed more frequently a systematic approach (17 times or 39.5% of the strategies in the unit) and less often a non-systematic approach (10 times or 23.3%). Partially systematic approaches appeared 16 times (37.2%). Table 3 summarizes the above data and shows that the participants most frequently used partially systematic strategies.

As this study aimed to investigate the effect of the instructional intervention on the dependent variable, we conducted a Cochran's Q test to determine if the percentage of the employment of each debugging strategy was different at different learning units. Sample size n was adequate to use the χ^2-distribution approximation, since, after subtracting the frequency of responses where scores were the same for all related groups, it was greater than 4 and, after multiplied by the number of related groups, it was greater than 24. The percentage of the employment of systematic strategies was statistically significantly different at the different learning

Table 3 Frequency distribution of debugging strategies across the learning units

	Exploring		Animations		Stories		Games		Total	
Debugging strategy	Count	Column N %	Count	Column N %	Count	Column N %	Count	Column N %	Count	Row N %
Systematic	5	11.6%	9	21.0%	7	16.3%	17	39.5%	38	22.1%
Partially systematic	21	48.9%	21	48.8%	20	46.5%	16	37.2%	78	45.3%
Non-systematic	17	39.5%	13	30.2%	16	37.2%	10	23.3%	56	32.6%
Total	43	100.0%	43	100.0%	43	100.0%	43	100.0%	172	100.0%

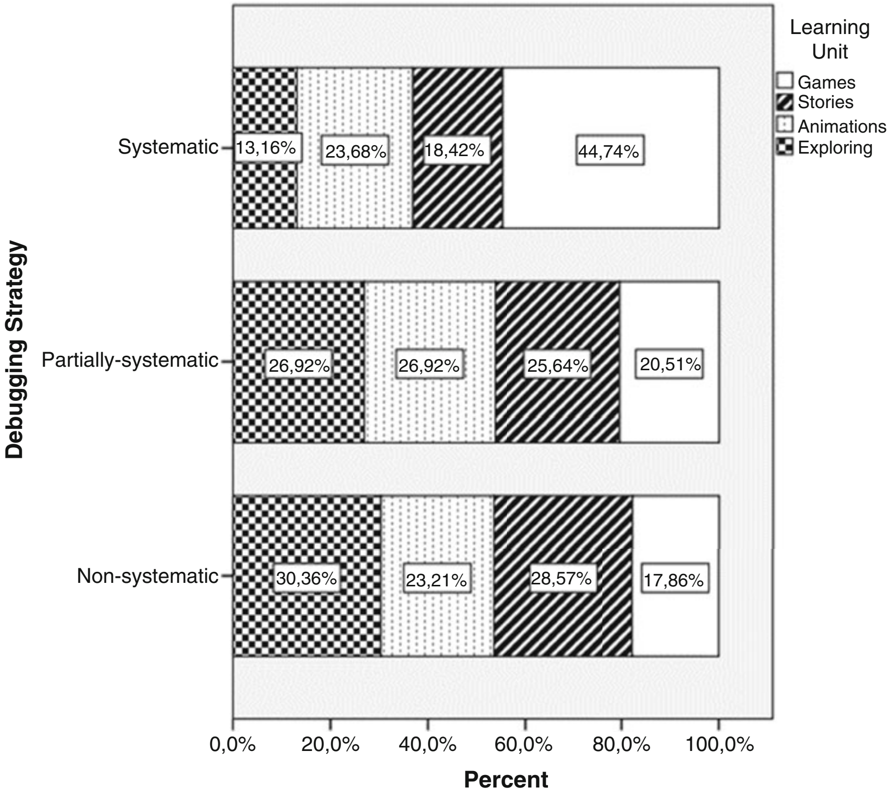

Fig. 4 Stacked bar plot showing the percentage of each strategy across the learning units

units, $\chi^2(3) = 8.737$, $p = 0.033$. Exact McNemar's tests were used to assess all pairwise comparisons. A Bonferroni correction was applied with statistical significance accepted at $p < 0.008$, given that there were six pairwise comparisons. Post hoc tests revealed that the percentage of systematic strategies employment at the *Games* unit was statistically significantly higher compared to the percentage of employment during the *Exploring* ($p < 0.001$) and the *Stories* ($p = 0.002$) units. Figure 4 shows the difference in students' debugging of their code in a systematic way between the *Exploring* (5 times or 13.2%), the *Stories* (7 times or 18.4%), and the *Games* units (17 times or 44.7%). There were no statistically significant differences between the *Exploring* and the *Animations* ($p = 0.125$) units, *Exploring* and *Stories* ($p = 0.625$), *Stories* and *Animations* ($p = 0.625$), and *Animations* and *Games* ($p = 0.021$), regarding the employment of the systematic debugging strategy.

Cochran's Q test was also conducted to determine if the percentage of the employment of partially systematic and non-systematic strategies was different between the four learning units. The analysis did not reveal any significant difference neither between the employment of partially systematic strategies,

$\chi^2(3) = 0.872$, $p = 0.832$, nor between the employment of non-systematic strategies, $\chi^2(3) = 2.143$, $p = 0.543$, during the introductory, the arts-themed, the digital storytelling, and the games units. Therefore, we cannot reject the null hypothesis and cannot accept the alternative hypothesis.

6 Discussion

This paper investigated the effect of a CT instructional intervention on students' testing and debugging proficiency level and strategy use. Given that the participants engaged in debugging activities in a visual programming environment, the errors were not related to the syntax of the programming language, but rather focused on the CT practice of "making sure things work and finding and solving problems when they arise" (Creative Computing Lab at the Harvard Graduate School of Education 2014). To strengthen the validity of the research, we used multiple sources of data.

Analysis of the collected data showed that the participants' proficiency level regarding the CT practice of testing and debugging was low or medium. We measured the highest mean score of this practice after the *Games* learning unit, finding that it was statistically significantly different from the mean scores measured immediately after the completion of both the *Exploring* and the *Stories* units. However, it did not differ from the score of the *Animations* unit, which was statistically significantly higher compared to the *Exploring* and the *Stories* units. The mean score of the CT practice for *Stories*, finally, was statistically significantly lower than the mean of the previous (*Animations)* and the following units (*Games)*. The pairwise comparisons between successive units of the intervention suggest that the special characteristics of each unit can have a significant effect on the testing and debugging proficiency level, but students developed their proficiency level of testing and debugging after the full sequence of CT-related activities that we applied.

Since 1986, Perkins and Martin focused on thought processes while debugging, arguing that limited development of problem-solving strategies could result in code bugs. The analysis of our data showed that during the debugging process, the participants more frequently applied procedures considered as partially systematic or non-systematic. However, the null hypothesis of equal percentages of use of each strategy category between the learning units could not be accepted, as the students applied a systematic approach to *Scratch* code debugging to a greater extent when they engaged in digital games debugging, as compared to when they debugged programs of the introductory unit and stories-related programs. Nevertheless, we found no statistically significant differences regarding the percentages of use of the partially and non-systematic strategies between the units.

Our results, therefore, suggest that students' engagement in digital game debugging activities in a visual programming environment can help improve their level of testing and debugging CT practice and as well their use of systematic debugging strategies. These findings further support the claims of other researchers who have highlighted the positive impact of digital game-related activities on the improvement of error detection strategies and the development of programming concepts to beginners (Miljanovic and Bradbury 2017; Yoon et al. 2014). During our instructional intervention, the games-related debugging activities came after a series of other activities, as described. It may be assumed that a sequence of debugging activities like the one we applied, whose last part includes games-related debugging challenges, may foster the development of CT-related skills.

The fact that we measured the highest level of proficiency regarding the practice of testing and debugging in the *Games* unit also leads to hypotheses about the special characteristics of the activities that led to specific effects on the CT practice. During this unit, the students gained experience with the CT concepts of conditionals, operators, and data, but also with all four CT practices. In contrast, during the *Stories* unit, in which we measured the lowest level of proficiency, we engaged the students in activities that required better fluency with the CT concepts of events and parallelism. During the previous unit (*Animations*), the students had experimented with the same concepts, while at the first one (*Exploring*), they had familiarized themselves with the concept of sequence. In addition, games are often more interactive than other types of programs, and usually include a goal that is challenging for the user to achieve. Finally, students only watched their story a few times, in contrast to playing the same game several times, each time with a different strategy to achieve the goal.

Our work has also led us to conclusions about the explicit teaching of the debugging strategies to the students. Our results show that the use of systematic strategies increased from the beginning of the course until the end, even though explicit teaching of an iterative, systematic process of debugging, e.g., like the one Böttcher et al. (2016) taught first-year students, did not take place. Taking into account both the quantitative and the qualitative data, we can summarize that the ability to debug in a systematic way has been developed through debugging experiences, enhanced by discussions and guiding questions in pairs and plenary. This concurs well with the Socratic method proposed by Wilson (1987) and is in line with the constructivist conceptions of learning and the social-cognitive theory. It is also consistent with the results of many relevant studies presented in the theoretical part of the chapter indicating that students learn from their mistakes only when they understand the wrong mental models that led to these errors (Chmiel and Loui 2004; McCauley et al. 2008; Robertson et al. 2004; Wilson 1987). However, many researchers have argued that explicitly teaching students how they have to work when debugging computer programs can be more effective than a natural development of the same skill (Böttcher et al. 2016; Kessler and Anderson 1986; Michaeli and Romeike 2019).

The unique contribution of this study is the focus on the process that young beginner programmers follow while applying testing and debugging, a CT practice that has not gained much attention from recent research unlike most CT concepts. Furthermore, this study focused on the beginner programmers-students of primary school that engaged in CT-related activities during their regular school program (and not in an after-school club). In addition, a combination of data collection tools has been applied to capture the most accurate view of the students’ thought processes while correcting code errors in a visual programming environment.

Finally, our study has some limitations within which our findings need to be interpreted carefully. First, the effect of exogenous variables on the levels of the dependent variables cannot be ruled out. Order effects, related to the order that participants are exposed to the various conditions or levels of the independent variable, are common drawbacks of repeated-measures designs and often result in either performance reduction (due to fatigue) or improvement (due to learning gained over time). Given that this study aimed to investigate the effects of a specific sequence of activities on students’ testing and debugging skills and strategies, we did not try to control order effects by counterbalancing, but future work could concentrate on investigating the effects of the same activities under a different sequence. Future work could also examine the effects of pair programming on students’ testing and debugging proficiency level and strategy use in comparison with solo programming. Finally, the difficulty of quantifying the phenomena under study and the possible Hawthorne effect (Monahan and Fisher 2010), in which participants attempt to modify their behavior in response to the researcher’s expectations, must be taken into account.

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A Two-Year Evaluation of Distributed Pair Programming Assignments by Undergraduate Students

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1 Introduction

Pair Programming (PP), as an element of Extreme Programming, has a long history in the software industry. The many benefits of PP are also considered important in the teaching of programming. Collaboration, sharing of knowledge and skills, as well as easier error detection and correction, are some of the factors that assist pairs of students in implementing programs. More recently, specially designed educational programming environments have given rise to Distributed Pair Programming (DPP), where pairs of students apply PP remotely anywhere and at anytime. A number of plugins for Eclipse IDE were built to support DPP in Computer Science Education. Although they cover the basic requirements of DPP, they could not address drawbacks of PP, such as unequal contributions from each member of the student pair.

Most of the research findings concern PP and a few studies investigated DPP. Studies in the field of DPP aimed to evaluate the effectiveness of DPP in student performance, DPP versus solo programming or DPP versus co-located PP (Duque and Bravo 2008; Hanks 2008) and other studies tested productivity and code quality between DPP and PP and concluded that virtual and co-located teams can produce comparable software. Researches on pair formation and pair compatibility in DPP are few.

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Our previous work in the field lies in the area of DPP. We conducted several evaluations in authentic learning conditions in order to investigate the impact of DPP in a typical Java course, using an educational DPP system known as SCEPPSys. In this paper, we focus on analyzing students' responses to a questionnaire completed at the end of the course, for two consecutive academic years; this is in conjunction with data from the log files of SCEPPSys, as well as data regarding the performance of students in their assignments and exams in order to validate the results from the questionnaire. The following issues are investigated: overall experience with DPP, preference in working individually or collaboratively on programming assignments, selection criteria, and satisfaction with partner, benefits, and shortcomings of DPP assignments.

The rest of the paper is organized as follows. In the next sections, related works in the field are presented (Sect. 2), which is followed by the research questions and the context of the study (Sect. 3). Section 4 presents the results and discussion. Finally, in Sect. 5, conclusions are drawn.

2 Related Works

There are various benefits of PP (Cockburn and Williams 2000) and DPP (da Silva Estácio and Prikladnicki 2015). According to Cockburn and Williams (2000), the most significant benefits of PP are: the detection of errors during coding; better program design and shorter code length; faster solution of problems; enhanced learning of system and software development; the acquisition of communication and collaboration skills; and finally, pairs seem to enjoy programming more.

Many educational applications have been developed to facilitate pair programming at a distance, the evaluations of which have generally shown a positive attitude toward DPP (Boyer et al. 2008; Hanks 2008; Muller and Padberg 2004). Students seem to enjoy distributed collaborative work considerably more than solo programming (Boyer et al. 2008; Zacharis 2010). A meta-analysis of PP studies showed that students' satisfaction was overall higher when working in pairs compared to working solo (Salleh et al. 2010). A study of the cognitive, affective, and social experiences of students in an introductory programming course found that students have a positive attitude toward pair programming, describing it as more motivating, engaging, and less frustrating (Celepkolu and Boyer 2018). Asnawi et al. (2019) developed a tool to facilitate PP. They conducted an experiment to evaluate the students' performance with and without using the tool. Results showed that the tool can help improving students' performance in terms of quality of codes, and lessen their time in completing their coding. Xu et al. (2020) studied the influence of periodic role switching intervals on PP performance and suggest to perform frequent role switches of the driver and navigator every 20–30 min.

In a recent systematic literature review on DPP, da Silva Estácio and Prikladnicki (2015) concluded that the effects of DPP on code quality are mixed, with two studies reporting negative and two studies reporting positive effects. More specifically, DPP was found to have: a positive effect on knowledge (1 study); has no effect (1 study) or has a positive effect (1 study) on productivity; has a positive effect on communication (1 study); has a negative effect on students' effort (1 study). Regarding the use of DPP for the teaching of programming, mixed results were recorded regarding students' performance, while a positive effect was recorded for grades, productivity, motivation, confidence, and learning.

In a more recent study Kuttal et al. (2019) empirically investigated whether and how technology-mediated remote pair programming hinders online students of same- and mixed-gender pairs.

Saltz and Heckman (2020) reported on a case study that explored student activity within online video-based breakout rooms via a Structured Paired Activity (SPA) methodology which is adapted from the concept of Paired Programming. Initial qualitative results suggest that the use of SPA in online breakout rooms increases student engagement and process effectiveness.

The main drawbacks observed in earlier DPP studies were the absence of awareness indicators (e.g., users could not point at code lines to indicate problems), lack of physical interactions among programmers and the need for stable and fast Internet connection (Hanks 2004; Stotts et al. 2003). In their study, Canfora et al. (2003) found that distributed pairs tended to stop collaboration and began working as solo programmers, while Schümmer and Lukosch (2009) noticed that role switches did not occur as often as expected during DPP sessions. The latest DPP applications have eliminated most of the aforementioned problems. Additionally, the system used in our study is designed to structure or "script" interactions between pair programmers in order to gain the most out of pair programming.

3 Research Questions and Methodology of the Study

3.1 The DPP System SCEPPSys

DPP is usually practiced using a real-time application for collaborative coding. Although various solutions exist to facilitate collaboration over distance, most of them lack educational features and do not cover the needs of novice programmers (Ying and Boyer 2020). We developed a system called SCEPPSys (Tsompanoudi et al. 2015) with the aim of supporting students to do DPP assignments.

SCEPPSys runs as an embedded application within the Eclipse IDE. A significant number of Eclipse-based solutions can be found in the literature (Boyer et al. 2008; Salinger et al. 2010; da Silva Estácio and Prikladnicki 2015), none of which, however, provides sufficient support to facilitate DPP for teachers or novice programmers. SCEPPSys includes some unique features that assist instructors to set up programming assignments, as well as some features to support novice (pair) programmers during the problem-solving process.

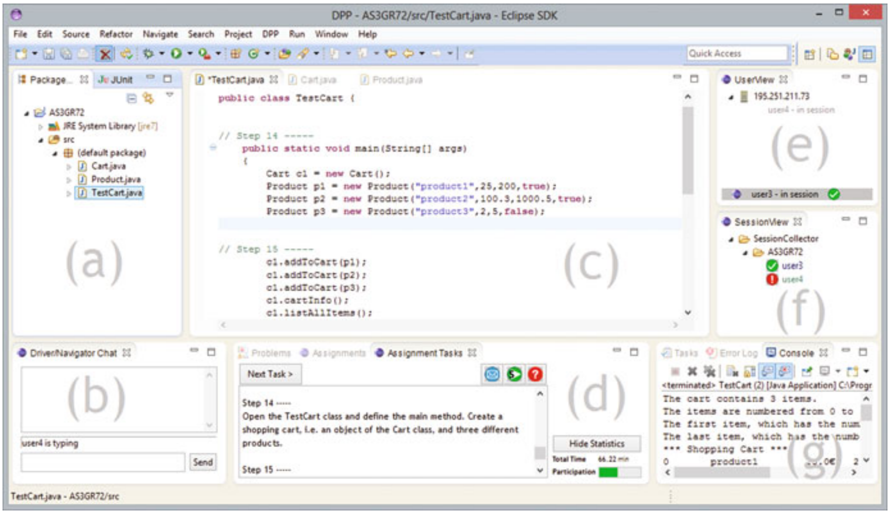

Fig. 1 Screenshot of a DPP session

SCEPPSys' distribution comprises of an Eclipse plugin installed by students and a web-based administration environment used by instructors for scripting DPP. The plugin (Fig. 1) includes typical features of DPP systems, such as providing a shared assignment (Fig. 1a), a shared editor (Fig. 1c), supporting the roles of the driver and navigator, and a text-based communication tool (Fig. 1b). In order to start a DPP session, both students must log in to the system (Fig. 1e), while assignments are solved synchronously. The user in the driver role is responsible for typing the Java code, while the second user, the navigator, reviews the inserted code. Remote code highlighting (a basic gesturing feature), enables the navigator to point out code parts in order to indicate potential problems. The remaining features, the so-called "awareness indicators," aim to provide pair programmers with information about user status and performed actions within the workspace (such as editing, saving, testing the code (Fig. 1g, etc.). However, it also includes some unique features that serve specific didactical needs: assignments comprising small, manageable tasks, or steps associated with specific didactical goals, or else OOP concepts (Fig. 1d); hints can be retrieved for each task that support students in completing them.

SCEPPSys also records a variety of information during the problem-solving process, and calculates statistics for each student per assignment. The statistics reported are the following: contribution of the first and second student (number of characters); total time spent in solving an assignment (in minutes); number of steps solved according to role distribution policy; driving time spent in solving an assignment (in minutes); driving time of first and second student; driving/total time ratio; number of sync runs; non-driving time of first and second student; number of role switches; number of retrieved hints; number of messages sent by first and second student using the embedded chat tool.

Table 1 Course outline

Course	Object-Oriented Programming
Semester/duration	3rd/13 weeks, 3 h per week
Programming language	Java
Syllabus	Objects and classes (necessity of using classes); class definition (fields, constructors, methods); Constructing objects and calling methods (main); Class associations; Groups of objects (array, ArrayList); Inheritance, polymorphism, and overriding; Abstract classes and interfaces; Graphical User Interface (constructing a simple GUI, event handling, interaction with domain classes); Collection framework of Java; Manipulation of text and binary files

3.2 Course Outline

The study presented in this paper took place in the context of a third-semester undergraduate "Object-Oriented Programming" course for the academic years 2015–2016 and 2016–2017. The OOP concepts are approached through hands-on exercises carried out in lab sessions. Information regarding the course is summarized in Table 1.

3.3 DPP Assignments

For the academic year 2015–2016, ninety-four (94) students participated, making up forty-seven (47) pairs. In the paper, we refer to them as the 2015–2016 group or the first group. For the academic year 2016–2017, eighty-eight (88) students participated, making up forty-four (44) pairs, which we refer to as the 2016–2017 group or the second group.

Within the course context, students carried out DPP assignments in pairs using the educational DPP system SCEPPSys. Important information about the assignments that were set is summarized in Table 2. There were six assignments for the 2015–2016 academic year and only five for 2016–2017, due to some time constraints in the academic calendar. The assignments, however, covered the same learning units of the course for both years. As can be seen in Table 2, the participants covered the same topics in the first three assignments for both years. However, the topics for assignments four and five that had been set in the first academic year (2015–2016) were both covered in the fourth assignment of the following year (2016–2017). Lastly, assignment six of the former year corresponds to assignment five of the latter.

The number of classes, the number of steps, and the lines of code (based on the instructor's solution) for each of the assignments for both years are presented in Table 3. More specifically, the first assignment in 2016–2017 required nearly

Table 2 DPP assignments

	2015–2016	2016–2017
Participants (DPP assignments)	94 (47 pairs)	88 (44 pairs)
Participants (questionnaire)	57	78
Prior programming knowledge	1st semester "procedural programming course based on C"	
Prior experience with DPP	None	
DPP system	SCEPPSys	
Group formation	Free selection of partner	
Assignments	1. Class definition, main	1. Class definition, main
	2. Class associations	2. Class associations
	3.Object collections – ArrayList	3.Object collections – ArrayList
	4. Inheritance & polymorphism	4. Inheritance & polymorphism, GUI, event handling
	5. GUI, event handling (& inheritance)	
	6. Binary files (& inheritance, ArrayList, Comparator)	5. Binary files (& inheritance, ArrayList, Comparator)

twice the number of lines of code in comparison to the corresponding assignment of the previous, making it thus more demanding concerning the code length and consequently the required time. Also, the fourth assignment in 2016–2017, which, as explained above, covered the material for both the fourth and fifth assignments of 2015–2016 was obviously more demanding in terms of lines of code. Thus, it should be noted that when the results for the fourth assignment of 2016–2017 are presented, they are compared to the corresponding results for the fourth and fifth assignments of 2015–2016. For the same reason, the results of the fifth assignment of the 2016–2017 group are compared to the results of the sixth assignment of 2015–2016 group.

We asked students to assess the degree of difficulty for each one of the DPP assignments on a scale of 1–5, where 1 = not difficult, 2 = of little difficulty, 3 = of average difficulty, 4 = difficult, 5 = very difficult. Students' difficulty assessments for each assignment are presented in Table 4. It appears that there was no statistically significant difference for assignments 1, 2, 4, and 5 between the 2 years, but there was a statistically significant difference for assignment 3 which seems to have been more difficult for the participants in 2016–2017 ($Z = 2.001$, $p = 0.045$, $r = 0.17$)).

Based on the results regarding students' difficulties (Table 4), it is clear that the fundamental concepts of inheritance and polymorphism, as well as GUI creation and event handling cause an average degree of difficulty to students. The combination of the aforementioned concepts with binary files adds complexity and increases the degree of difficulty.

Table 3 DPP assignments

Learning unit	Assignment		Number of classes (Steps)		LOC (Lines Of Code)	
	2015–2016	2016–2017	2015–2016	2016–2017	2015–2016	2016–2017
Class definition, main	#1	#1	2 (13)	2 (17)	90	175
Class associations – Relationship	#2	#2	3 (16)	3 (17)	120	143
Object collections – ArrayList	#3	#3	3 (23)	3 (20)	160	157
Inheritance and polymorphism	#4	#4	4 (16)	6 (24)	114	166
GUI, event handling, inheritance	#5		6 (24)		135	
Binary files (+inheritance, ArrayList, Comparator)	#6	#5	5 (5)	5 (5)	210	257

Table 4 Students' responses regarding the difficulty of assignments

	2015–2016		2016–2017				
Assignment	Mean	Stdev	Mean	Stdev	Z	p	r
#1	1.57	0.80	1.58	0.87	−0.097	0.923	−0.01
#2	1.75	0.69	2.01	0.83	1.846	0.065	0.16
#3	2.29	0.80	2.63	0.88	2.001	0.045	0.17
#4	3.03	0.98	3.35	0.97	1.818	0.069	0.16
#5	4.09	0.95	4.34	0.81	1.538	0.124	0.14

3.4 Research Questions

The study aimed to investigate the following research questions (RQ):

- **RQ1**: How do students evaluate their experience of DPP assignments?
- **RQ2**: Does the choice of partner by the student themselves lead to effective pair formation?
- **RQ3**: What are students' perceptions of the benefits of DPP assignments?
- **RQ4**: What factors hinder student collaboration and experience in DPP assignments?

3.5 Instruments and Data Analysis

The data analyzed in this study were collected from the questionnaire distributed to students at the end of the DPP assignments and the system's log files. Descriptive statistics (percentage, mean, and standard deviation, or median) were used to present students' data. Statistical analysis involved the application of chi-square tests of independence for the questions pertaining to RQ1 and RQ2 and the computation of Spearman's rank-order correlation coefficient. Mann-Whitney tests were applied for the questions pertaining to RQ3 and RQ4. Effect size was calculated for each test.

The questionnaire is given in an annex and the following items were used to investigate each of the RQs:

RQ1: Q1, Q2, Q6, Q7, Q8.
RQ2: Q3, Q4, Q6, Q7, Q8, Q9, Q10.
RQ3: Q5, Q11.
RQ4: Q6.

3.5.1 Log Files

To further analyze students' responses to RQ3, we used some of the recorded data that are logged by the system during the DPP sessions. For each assignment, the number of exchanged messages, sync runs, total time, and driving time were analyzed. In more detail:

- The number of exchanged messages refers to the number of messages sent through the embedded chat tool of the plugin.
- The number of sync runs is the total number of program executions that were performed by each pair.
- Total time refers to the time pairs spent solving the assignment using the features of the plugin.
- Driving time is calculated taking into account the time students spent writing the program code.

4 Results and Discussion

In this section, the results of the study are analyzed and discussed.

Table 5 Overall experience of DPP assignments

	2015–2016	2016–2017
Very bad	5%	4%
Bad	5%	3%
Neutral	7%	18%
Good	50%	50%
Very good	33%	26%
Total	100%	100%

4.1 Overall Experience (RQ1)

Questions (Q1) and (Q2) investigate students' initial overall experience of DPP assignments. Table 5 shows students' responses to (Q1). The chi-square test of independence showed no statistically significant association between the groups of participants of each year ($X^2 = 4.428$, df $= 4$, $p = 0.351$, $\phi_c = 0.18$).

The majority of students in both years gave a positive evaluation on their overall experience of the distributed and collaborative solution of assignments (combined "good" and "very good": 83% and 76% in 2015–2016 and 2016–2017, respectively). On the other hand, a combined 10% (2015–2016) and 7% (2016–2017) evaluated the overall experience of DPP assignments negatively. Just over double the percentage of students in the 2016–2017 group (18%) stated that their experience was neutral in comparison to the 2015–2016 group (7%).

In order to study whether students' evaluation of their overall DDP assignments experience is correlated to their performance on the course, Spearman's correlation coefficient was computed. In this statistical test, the final marks of 52 (out of 57) students of the first group and the 67 (out of 78) students of the second group that took part in the final exams were analyzed. The distribution of students' replies for (Q1), for both groups and for every mark on a scale of 1–10 is presented in Fig. 2, while the mean value of students' experience in relation to every mark is presented in Fig. 3. Spearman's Rho suggests that there is no correlation between students' final mark in Java and how they evaluated the DPP experience for either group (2015–2016: $r_s = -0.049$, $p = 0.730$; 2016–2017: $r_s = -0.019$, $p = 0.876$).

In an attempt to investigate the potential reasons that students reported a bad or a very bad experience on DPP assignments, we analyzed their responses to the following questions: (Q6) a closed-type question regarding various collaboration problems; (Q7) an open question for comments regarding any aspect of the DPP assignments; and (Q8) about their grade in the previous introductory programming course. The main findings for the six students of the 2015–2016 group and the five students of the 2016–2017 group that reported a bad or very bad overall experience of DPP assignments are summarized in Table 6.

It is clear that for the 2015–2016 group, their bad experience in DPP assignments can be attributed to coordination problems with their partner (such as finding a time slot for collaboration), partner's lack of knowledge, and technical problems. The fact that half of the students in the first group had not passed (2 students) or

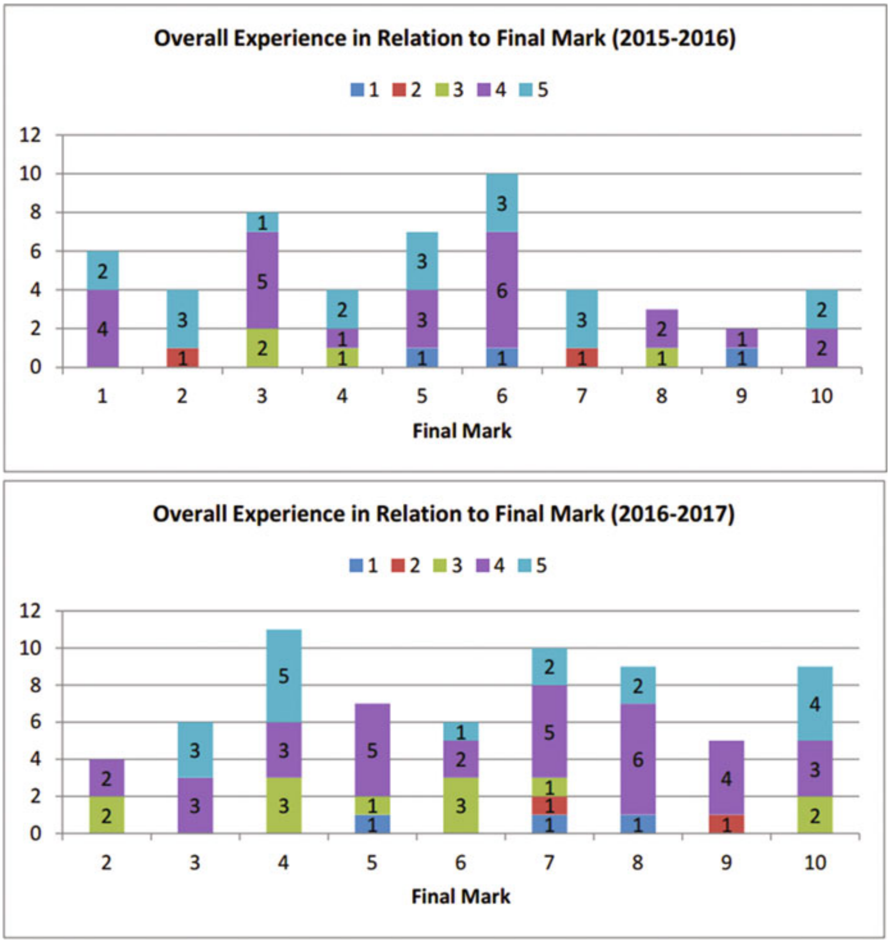

Fig. 2 Students' final marks in relation to their overall experience

had just achieved the minimum passing grade in the introductory programming course (1 student) (Q8) is probably related to students' experience not only on the DPP assignments but the course overall. Taking into account the technical and collaboration problems documented for this group, the following measures were taken which seem to have had a positive impact in dealing with issues that might have resulted in the students of the following academic year (2016–2017) having a bad experience.

- The infrastructure for hosting SCEPPSys was improved in order to deal with the technical issues.
- Students were informed about the good and bad practices during a collaboration session.

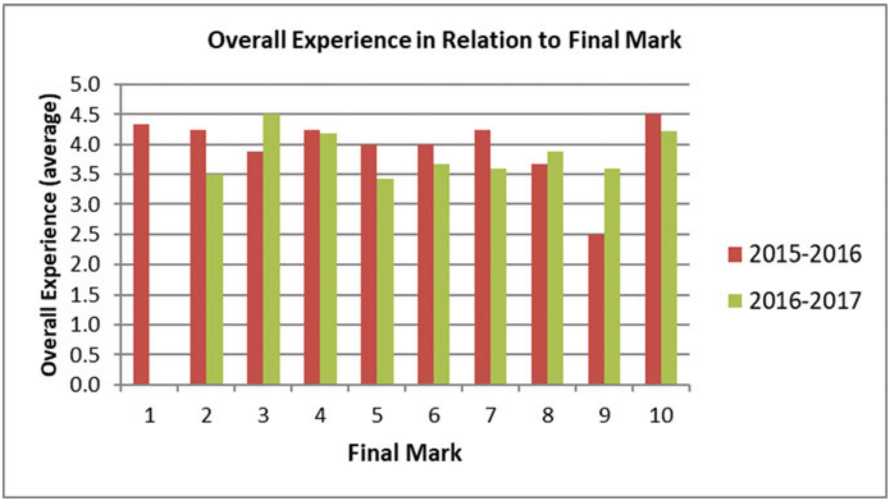

Fig. 3 Students' final marks in relation to mean overall experience

Table 6 Potential reasons for students' bad experience of DPP

	2015–2016 (10% – 6 students)	2016–2017 (7% – 5 students)
Fail or minimum passing grade in the introductory programming course	3	1
Technical problems	3	1
Coordination problems with partner	3	1
Dominating role of partner	1	1
Partner's lack of knowledge	3	1
Difficulties in using the plugin	2	2
Does not believe in the benefits of DPP	1	–

- Students were given some guidelines which they should take into account, for a more effective pair formation.

Although it appears that these actions had a definite positive effect on the second group's DPP experience, students' difficulties were not altogether eliminated. For example, in both groups, two of the students that reported a bad experience faced difficulties with the plugin. In addition, there are some technical problems that cannot be easily dealt with and are connected to the students' individual home infrastructure, of which the most important are to appropriately configure students' hardware and software, which is usually used for DPP assignments and to ensure a stable Internet connection.

Students' responses for (Q2) are presented in Table 7. The chi-square test of independence showed that there was a statistically significant association between the two groups ($X^2 = 6.221$, $df = 1$, $p = 0.013$, $\phi = 0.22$). Before analyzing

Table 7 Preferred mode of carrying out programming assignments

	2015–2016	2016–2017
Individually	13 (22.8%)	7 (7.7%)
Collaboratively	44 (77.2%)	71 (92.3%)
Total	57 (100%)	78 (100%)

the results, we should point out that students in both groups had experience in carrying out programming assignments individually from the previous "Procedural Programming" course. Regarding the results, we can see that the percentage of students that prefer to carry out assignments collaboratively using SCEPPSys increased in the 2016–2017 group (92.3%), which as mentioned, is statistically significant. This can be attributed to several reasons, one being the measures taken for dealing with technical and coordination problems that were noted for the first group (2015–2016).

Although the vast majority of students in both years stated they preferred to work collaboratively, we wanted to investigate the reasons why some students chose the preference of doing their programming assignments individually. The results for (Q1) and (Q2) were analyzed, in combination with their responses regarding the problems encountered during DPP assignments (Q6). Out of the 13 students from the 2015–2016 group, who in (Q2) stated that they would prefer to work individually, only one student evaluated the DPP experience as bad, also stating connection problems (Q6), while two students evaluated the experience as neutral. The other 10 rated it as good. Similarly, for the 2016–2017 group, out of the seven, whose preference was to work individually, six evaluated their overall DPP experience as good, while one evaluated it as neutral. We can, therefore, infer that in spite of their positive experience with DPP, it is the individual preference of some students to work alone on their programming assignments. Nevertheless, teamwork, collaboration, and agile software development techniques are important skills in the software industry and DPP assignments can be used as a first step toward cultivating such competences.

4.2 Pair Formation (RQ2)

In the present study, students chose their partners on their own. During the first academic year (2015–2016) students were not given any particular guideline or hint. In the second academic year (2016–2017), however, students were given some advice as regards effective pair formation based on the results of the qualitative analysis of students' responses to the questionnaire from the previous application of DPP the year before (Xinogalos et al. 2017). In particular, students were told to take into account each other's schedules, as well as whether they both have common available slots for collaboration.

In order to investigate RQ2, as to whether students choosing their own partners leads to effective pair formation, their responses to question (Q3) concerning

Table 8 Selection criteria for partners

	2015–2016	2016–2017
Being a friend	87.7%	47.4%
Having the same level of programming knowledge as me	10.5%	28.2%
(I think) we are compatible as personalities[a]	–	21.8%
Other	1.8%	2.6%
Total	100%	100%

[a]This choice was included only in the questionnaire for the 2016–2017 group

Table 9 Satisfaction with partner

	2015–2016	2016–2017
Yes	53 (93%)	75 (95%)
No	4 (7%)	3 (5%)
Total	57 (100%)	78 (100%)

students' selection criteria of their partner, and question (Q4) regarding students' satisfaction with their partner were analyzed.

The responses to (Q3) are presented in Table 8. The chi-square test of independence showed a statistically significant association between the two groups ($X^2 = 24.614$, $df = 2$, $p < 0.001$, $\phi_c = 0.43$). It needs to be mentioned here that the predefined answer "(I think) we are compatible as personalities" was added to the questionnaire completed by the 2016–2017 group, in order to investigate whether friendship or similar personalities were criteria for choice of partner. The results showed that personality was an important criterion for one-fifth of the students (21.8%) in the 2016–2017 group, while it was not considered to be synonymous to friendship. In both years, friendship was the main selection criterion of a partner (2015–2016: 87.7%, 2016–2017: 47.4%). An important difference between the two groups is the criterion: "having the same level of programming knowledge" which was the main reason stated as choice of partner for 28.2% of the students in the 2016–2017 group, in contrast to 10.5% in the 2015–16 group. It would appear that the hint given to the second group of students (2016–2017) regarding the importance of pair formation resulted in more informed and thoughtful choices.

It is interesting to note that even though participants were given the option of elaborating on their selection criteria, extremely few did so.

Students' responses to (Q4) are presented in Table 9. The chi-square test of homogeneity showed no statistical difference between the two groups ($X^2 = 0.674$, $df = 1$, $p = 0.412$, $\phi = 0.07$). The vast majority of students in both groups (2015–2016: 93%, 2016–2017: 95%) were satisfied with their partners. These results support those found by Jacobson and Schaefer (2008) who reported that less than 5% of the students have compatibility problems when they select their partner on their own.

Even though the vast majority of students in both study years were satisfied with their choice of partner, we wanted to investigate what the potential reasons were for those few students who stated that they were dissatisfied with their partner. Their responses to the following questions were analyzed: (Q6) a closed-type question regarding various collaboration problems; (Q7) an open question for comments about any aspect of the DPP assignments; (Q8) referring to their grade in the previous introductory programming course; (Q9) as to how students view their partner's level of programming capability in comparison to their own; (Q10) regarding students' perceived pair compatibility in terms of programming capability. The last two questions were included in the questionnaire given to the 2016–2017 group, specifically to help us investigate whether students' reported dissatisfaction can be attributed to their perceived level of programming ability in comparison to that of their partner's, as well as the potential incompatibilities.

There were four participants from the 2015–2016 academic year and three from the 2016–2017 year who claimed to not be satisfied with their partner. The following findings arose from their responses.

- All four students from the first group (2015–2016) and one from the second (2016–2017) chose their partner on the basis of friendship, while the other two students from the second group had made their selection based on the belief that their personalities were compatible.
- All four students of the 2015–2016 group had similar programming skills with their chosen partners. More specifically, in their scores from the previous introductory programming course, it was indicated that three of the students were in pairs where both partners had low skills, while in the other student's pair formation, both partners had high skills. In contrast, for the 2016–2017 group, one student had similar programming (low) skills with their partner, while the other two students consisted of pairs where one's partner had low and the other's partner had high programming skills.
- The three students from the 2016–2017 group considered their partner to be weaker in terms of programming capability. Despite this fact, only one student considered themselves and their partner to be incompatible as far as programming capability was concerned, which could be a potential factor of partner dissatisfaction.
- The most serious problem stated by three of the students from the 2015–2016 group was their partner's lack of knowledge, in spite of the fact that all partners had similar skills in programming. Two students from the 2015–2016 group and one from the 2016–2017 group stated that they had problems in agreeing when to collaborate, while one participant from the 2015–2016 group claimed that their partner was unreliable.

This qualitative analysis sheds light on the dissatisfaction some students had with their partner. The reasons for this dissatisfaction are logical, but at the same time, it is difficult to take measures to completely avoid such issues from arising. We consider that giving students some hints on factors that they should take into account when choosing a partner on their own leads to fairly positive results.

Table 10 The benefits of DPP

	2015–2016		2016–2017				
Perceived benefit	Mean	St.Dev	Mean	St.Dev	Z	p	r
Sharing knowledge and skills with my partner	3.95	0.88	4.00	0.70	−0.150	0.881	−0.01
Quicker correction of logic and syntax errors	4.09	0.91	4.13	0.67	−0.233	0.816	−0.02
Less time for completing an assignment	3.68	0.93	3.46	1.00	−1.187	0.235	−0.10
DPP assisted me to learn programming	3.91	0.91	3.72	0.95	−1.228	0.220	−0.11
Learning programming was more pleasant	4.32	0.83	4.08	0.82	−1.936	0.053	−0.17
Most questions were answered through discussion with my partner	3.95	0.95	3.96	0.80	−0.302	0.762	−0.03
I was more confident about the correctness of my solutions	3.82	0.93	4.01	0.75	0.967	0.333	0.08
Feeling of responsibility for my participation in the assignments	4.16	0.84	4.21	0.67	−0.034	0.973	−0.00
It forced me to solve more assignments than I would if assignments were solved individually	3.25	1.48	3.13	1.35	−0.555	0.579	−0.05
DPP helped me improve the quality of my code	3.82	1.02	3.68	0.78	−1.583	0.113	−0.14

4.3 Perceived Benefits of DPP Assignments (RQ3)

An effort was made in the context of this study to investigate students' perceptions on the various benefits of DPP.

Students' responses to (Q5) are presented in Table 10. The Mann-Whitney test for comparing the two distributions was applied and no statistically significant difference was recorded.

The three most prominent benefits of DPP assignments for both groups are the following:

- "Learning programming was more pleasant"
- Students had a "feeling of responsibility for their participation in the assignments, without, however, "feeling forced to solve more assignments than they would have if the assignments were solved individually"
- "Quicker correction of logic and syntax errors." Debugging a program is widely known to be a time-consuming and demanding process. Although instructors stress the need for incremental development and testing, students usually do not apply such an approach during program development. Especially in OOP, students tend to completely implement a class and write the main method for

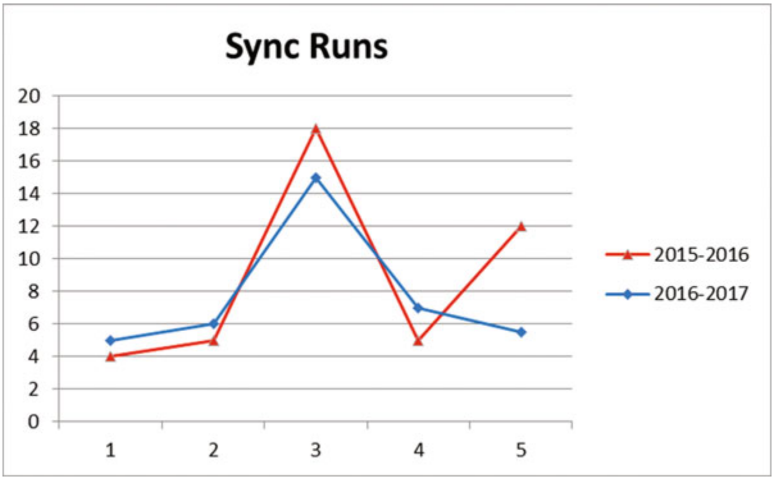

Fig. 4 Median of sync runs per assignment

testing their code afterward. In scripted collaboration, the idea of incremental development and testing can be reinforced by asking students to partially implement a class and create objects for testing each method from the very first steps, and reminding them in the textual description of the steps to run their assignment. Obviously, students can just ignore such advice. Based on the log files, the median number of sync runs per assignment ranges from 4 to approximately 18 for both groups (Fig. 4), which is an indication of incremental development and testing. The SCEPPsys approach to scripted collaboration is considered to have an impact on quicker correction of logic errors and possibly on the quality of code, as well. Regarding the difference in the median of sync runs between the two groups, we must note that: the first assignment of the 2016–2017 group had nearly twice as many lines of code as the corresponding assignment for the 2015–2016 group; the fourth assignment of the 2016–2017 group combined the material of the fourth and fifth assignment of the 2015–2016 group, therefore the median of sync runs for assignments four and five was calculated for each student of the 2015–2016 group in order to be compared to the number of sync runs of the 2016–2017 group for assignment four; the same procedure was followed with respect to sent messages, total time, and ratio driving time to total time; the fifth assignment of the 2016–2017 group actually corresponds to the sixth assignment of the 2015–2016 group (see Table 3). Consequently, for the 2015–2016 group, the median of sync runs for assignments four and five are presented under assignment #4 and the median of sync runs for assignment 6 is presented under assignment #5 in Fig. 4. The Mann-Whitney test for comparing the two distributions of sync runs was applied and no statistically significant difference was recorded.

The majority of students also reported the following benefits:

Fig. 5 Median of messages sent by each group per assignment

- *Sharing knowledge and skills* with their partner, and that *most questions were answered through discussion* with the. These results are confirmed by the data recorded in the log files that provide a strong indication of collaborative work and exchange of perceptions and knowledge. This can clearly be seen in Fig. 5, which presents the mean number of messages sent by the two groups per assignment, and where the mean for the 2015–2016 group ranges from 2–9, while the 2016–2017 ranges from 1–9 messages per assignment. The Mann-Whitney test for comparing the two distributions of messages sent was applied and no statistically significant difference was recorded. Although the number of messages sent through the embedded chat tool of the plugin was high, it must be noted that students in both groups claimed that they also used alternative means of communication (Q11), namely, Skype, Facebook, Discord, as well as their mobile phones; 51 out of 57 and 73 out of 78 students did so in 2015–2016 and 2016–2017, respectively. The results clearly show an enhancement of collaboration and communication, skills which are considered extremely important in the software industry generally, and more specifically in agile software development techniques.

- Students are more *confident* for the correctness of their solution, and, in addition, they believe that they write better *quality* code. Generally, it appears that students are more confident about their outcome when working in pairs.

We consider it important that students in both groups have a uniform and quite positive opinion regarding the benefits of DPP. Moreover, based on data from the log files, it appears that students devoted a great deal of time on collaboratively solving the assignments. As shown in Fig. 6, students spent approximately two to three and a half hours on each assignment, which shows that they took pair work and collaboration seriously. Based on the driving/total time ratio calculated from

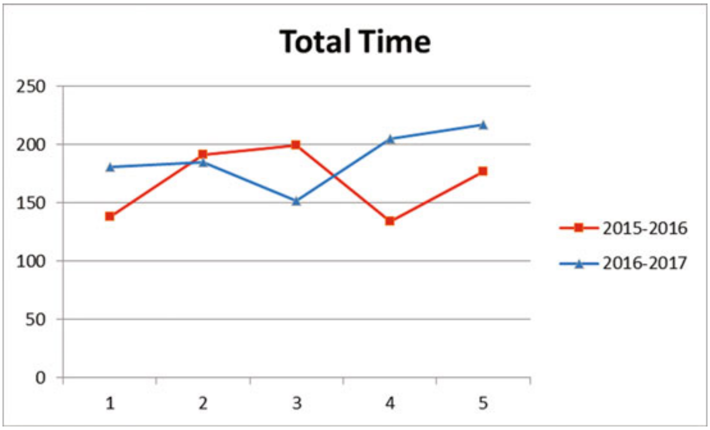

Fig. 6 Median of total time for each group per assignment

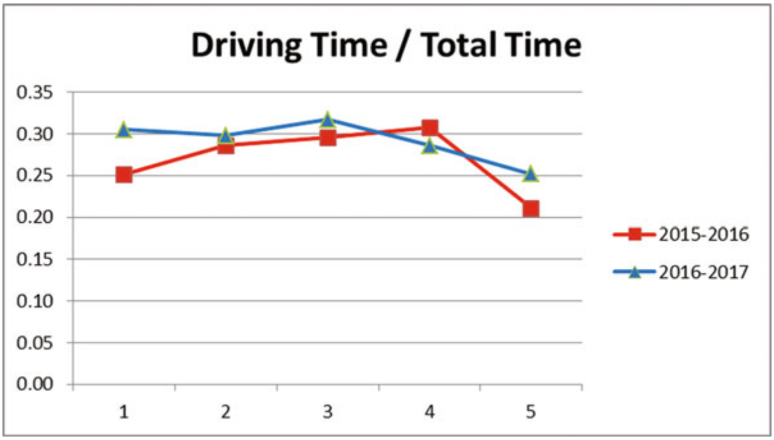

Fig. 7 Median of the ratio driving time/total time for each group per assignment

the data of the log files, the actual writing of the code took up between almost one-fifth and one-third of the total time spent on the assignment for both groups, as shown in Fig. 7. This is a strong indication that most of the time was spent on studying the corresponding material, reading hints, debugging the program, as also denoted by the number of sync runs, communicating with the collaborator, and of course thinking about the solution. The statistical test on the distribution of the 2 years in terms of total time spent on each assignment showed that there was a significant difference for assignments one ($Z = 2.033$, $p = 0.042$, $r = 0.22$) and four ($Z = 2551$, $p = 0.011$, $r = 0.25$), while the statistical test on the distribution of the 2 years in terms of the ratio of driving time/total time showed a significant difference only for assignment one ($Z = 2.862$, $p = 0.004$, $r = 0.31$). These differences in the distributions of the 2 years might be explained by the fact that the first

Table 11 Factors that hinder DPP

	2015–2016		2016–2017				
Perceived problem	Mean	St.Dev	Mean	St.Dev	Z	p	r
Coordination problems (collaboration time)	3.68	1.17	3.67	1.25	0.048	0.961	0.00
Unreliable partner	4.61	0.82	4.42	1.21	−0.243	0.808	−0.02
Partner's lack of knowledge	4.04	1.22	4.05	1.18	0.036	0.971	0.00
Dominating role of partner	4.63	0.84	4.35	1.20	−1.348	0.178	−0.12
Technical problems	3.04	1.07	3.13	1.25	0.779	0.436	0.07
Difficulty in using the plugin	4.05	0.93	3.67	1.19	−1.779	0.075	−0.15

assignment was more demanding concerning the code length than any of the others, and consequently, the required time was longer. Likewise, the fourth assignment for the 2016–2017 group was more demanding in terms of lines of code.

4.4 Perceived Shortcomings of DPP Assignments (RQ4)

Students' responses to (Q6) are presented in Table 11. The Mann-Whitney test for comparing the two distributions was applied and no statistically significant difference was observed. The results obtained from the first group of students in 2015–2016 were confirmed by the second group of students the following year. The highest factors to hinder DPP were, on the one hand, technical problems, stated to do so to a moderate extent that in several cases had to do with the students' infrastructure and Internet connection, on the other, to a slightly lesser extent, coordination problems.

5 Conclusions

OOP teaching and learning is accompanied by several difficulties. An important challenge is to increase students' interest by motivating them to practice implementing and debugging programs, which is undoubtedly a difficult and time-consuming task. This process can become more pleasant if students work in pairs. The advent of DPP and specially designed environments has given the chance for collaboration between pairs of students working remotely from anywhere, at any time. Although several benefits have been recorded in the literature, we consider it important to investigate the perception of students themselves on the effectiveness of DPP. With this aim, we prepared an online questionnaire that was filled-in by undergraduate students after a one-semester OOP course that required DPP assignments. Students used SCEPPSys for carrying out DPP assignments in Java throughout the semester. Data from the questionnaire completed by the students on the particular course was collected for two consecutive academic years. Moreover, data that are logged by the system during DPP sessions were analyzed for both years in order to validate students' perceptions and further investigate the RQs. At this point, we must note as a limitation of the study the fact that it did not include a larger number of participants each year. However, the findings attained in the second year confirmed those of the first year, which indicates that students have a positive perception of the DPP experience in learning programming.

The majority of students had a positive *overall experience* from the distributed and collaborative solution of assignments and stated that they would prefer to *work collaboratively* instead of individually on programming assignments. It is important to note that besides the well-known difficulties with OOP, no correlation was recorded between their performance in the OOP course and how students evaluated the DPP experience for both groups. No matter what the programming capability of the participants was, the majority reported a positive overall experience with DPP. Nevertheless, there was a small number of students, who stated that in spite of their positive experience with DPP, they still prefer to work individually. Had these students been informed about the importance of collaboration and teamwork in the software industry, perhaps, they would have been more willing to work collaboratively.

Allowing students to *form their own pairs* leads to a high degree of satisfaction, as Jacobson and Schaefer (2008) have also noted. The main selection criteria for choosing a partner seem to be *friendship*, followed by the perception that the partner has the *same level of programming knowledge*, and thirdly *personality compatibility*.

Our findings confirm more the benefits of (PP), which has been studied to a greater degree than (DPP) in the literature. Nevertheless, it appears that the most prominent benefits of DPP assignments lie in the fact that "learning programming becomes more *pleasant*," students have a "feeling of *responsibility* for their participation in the assignments," and there is "*quicker correction* of logic and syntax errors." The first and third benefits are in agreement with the findings by Cockburn and Williams (2000), while the second with those of Williams and Kessler (2001). Based on participants' responses and log data, it is clear that students worked collaboratively using besides the embedded text-based chat tool, several other communication channels (including Skype and Facebook), they executed their programs frequently, and they spent a lot of time on designing their solutions rather than just implementing them.

Finally, the two most prominent factors that seem to moderately hinder the collaboration and overall experience in DPP are *technical* and *coordination problems* (i.e., collaboration time). Technical problems in several cases had to do with students' infrastructure, but special attention should be given to guaranteeing a reliable institutional infrastructure. Regarding the coordination problems, it is apparent that the problem would be far more serious if actual physical presence in a particular location was required, which in effect can be managed with DPP assignments, and thus, we consider it an added benefit.

The findings of our research provide interesting implications both for instructors and researchers. The findings can help instructors understand how to implement

DPP in CS courses, starting from selecting an appropriate DPP tool with pedagogical features to pair formation and the overall application of DPP in a typical course. A DPP tool has to support not only students but also instructors by saving valuable information in order to understand how students develop programs in a collaborative manner and this is an issue that deserves further research.

A.1 Appendix

A.1.1 Questionnaire

Q1. *How would you evaluate the distributed, collaborative solution of the assignments as an overall experience? (1 = Very bad, 2 = Bad, 3 = Neutral, 4 = Good, 5 = Very good)*

Q2. *Based on your experience in DPP, would you prefer to work individually or collaboratively on programming assignments?*

Q3. *What was the main criterion for choosing your partner?*

Is a friend
Has the same level of programming knowledge as me
(I think) we are compatible as personalities (included only in the 2016–2017 questionnaire)
Other (please specify):

Q4. *Were you satisfied with your choice of partner?*

Q5. *To what extent do you agree that you gained the following benefits from DPP?*
(1 = totally disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = totally agree)
Sharing knowledge and skills with my partner
Quicker correction of logic and syntax errors
Less time for completing an assignment
DPP assisted me in learning programming
Learning programming was more pleasant
Most questions were answered through discussion with my partner
I was more confident for the correctness of my solutions
Feeling of responsibility for my participation in the assignments
It forced me to solve more assignments than I would if assignments were solved individually
DPP helped me improve the quality of my code

Q6. *To what extent did the following factors hinder collaboration and your experience of DPP?*
(1 = very much, 2 = much, 3 = moderately, 4 = not much, 5 = not at all)
Coordination problems (collaboration time)
Unreliable partner
Partner's lack of knowledge

Dominating role of partner
Technical problems
Difficulty in using the plugin
Q7. *Provide comments, observations, and proposals for improvement.*
Q8. *What was your grade in the previous introductory programming course?*
Q9. *Assess the programming capability of your partner in comparison to your own programming capability:*
My partner was weaker
My partner was better
We had about the same programming capability
Q10. *Assess your compatibility with your partner in terms of your programming capability*
Noncompatible
Sufficiently compatible
Very compatible
Q11. *Did you use alternative means of communication with your partner during the DPP sessions besides the embedded chat tool? If yes, please specify.* (open type question)

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Technology Readiness and Actual Use of Greek School Network by Primary Teachers

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1 Introduction

Information and Communications Technologies (ICTs), as a means to enhance the quality in education, provides opportunities for new learning environments and differentiated teaching practices, where its integration into the educational process is rather a systemic transformative process. Moreover, it is associated with various aspects, such as *technology infrastructure* (from micro level, i.e. school unit, to macro level, i.e. country-based communication networks and Internet provision), development and provision of valid and pedagogically sound *open educational resources* and new and reformed *school curricula* with emphasis on new literacies, both for students and educators (Sofos and Kron 2010). Many studies have addressed various challenges that arise when integrating technology into education:

- Expectations of teachers regarding the added value of ICTs in schools (Al-Bataineh et al. 2008)
- Absence of sound pedagogical scenarios related to the use of specific tools (Ertmer and Otternbreit-Leftwich 2010)
- Experience levels and self-efficacy of teachers about the actual use of ICTs in education (Ertmer and Ottenbreit-Leftwich 2010)
- Attitudes of teachers towards ICT (Drent and Meelissen 2008)
- Recognition, encouragement and guidance in the use of ICT (Tezci 2011)
- Teachers' characteristics such as age, gender, level of studies, teaching experience, etc. (Wong and Li 2008)
- Features of ICTs that encourage the adoption of innovation (Usluel et al. 2008)

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- Teachers' technological stress (Venkatesh et al. 2003)
- Existing educational policies (Jimoyiannis 2010)
- Initial teachers' education curricula (Fokides 2017; Fokides and Kostas 2020)

Bikos and Tzifopoulos (2011) suggested that the successful use of ICTs presupposes a continuum of educational policies, initial teacher education and in-service teachers' professional development initiatives. The international research IEA SITES 2006 (Brese and Carstens 2009; Law and Chow 2008) revealed that adequacy and training for the pedagogical use of ICTs are more important factors in predicting the use of ICTs in relation to mastering specific technical skills.

Moreover, constructs like technology readiness have been utilized as predictors for ICT use, examining how prepared teachers are for a new technology (Badri et al. 2014).

Parasuraman (2000) developed TRI to measure consumers' enduring propensities to embrace new technologies referring to four dimensions of technology beliefs that impact an individual's level of techno-readiness. In general, technology readiness differs from other constructs, such as Technology Acceptance Model (TAM), in that it measures beliefs an individual has about cutting-edge technology in general, while TAM measures acceptance towards a specific technology (Venkatesh and Davis 2000).

Technology readiness is a multidimensional psychographic construct, offering a way to segment user based upon their underlying positive and negative technology beliefs and could be measured with the Technology Readiness Index (TRI). TRI is using a scale to measure and classify individuals by their tendency to embrace and use new technologies for accomplishing goals in personal life and at work. This scale is tested and validated across numerous studies the last years and as a construct can be viewed as an overall state of mind resulting from a gestalt of mental enablers and inhibitors that collectively determine a person's predisposition to use new technologies.

Build upon previous work on technology readiness and factors influencing ICT adoption in education, this study aims to explore the technology readiness levels of Greek public school teachers and identify the relation between teachers' technology readiness and various demographic variables. This study is part of an empirical research aiming to explore teachers' views about the digital services and tools of Greek School Network (GSN) and their educational usage patterns and integration into school practice.

GSN initiative (Kalochristianakis et al. 2007) was part of Greece's systemic reform in education after 2000 and now is the national network of the Ministry of Education and Religious Affairs which safely interconnects all schools and entities supervised by the Ministry, provides services to students and teaching staff and provides e-learning and e-government services, helpdesk and support services.

Results of this study contribute both to the macro- and micro-social levels of the national educational policy, in terms of (a) pedagogical use of new media and ICT at the primary education as an integral part of school practice and (b) adaptation of strategies and curricula, in order to cultivate a stronger media philosophy among the teachers (Sofos and Kron 2010).

This chapter is organized as follows: The next section provides a background review, then the research methodology is described, and then results are presented and discussed. The chapter ends with a short discussion and conclusions.

2 Technology Readiness Index (TRI)

Technology Readiness Index (TRI) emerged from studies (Parasuraman 2000; Parasuraman and Colby 2015) on how to adopt new technologies and through a scale; it measures and classifies individuals with a tendency to adopt and embrace technology.

This construct is a set of mental activators and inhibitors that collectively determine a person's tendency to use new technologies (Parasuraman 2000). In 2000, Parasuraman published the first scale of technological readiness (TRI 1.0), a tool for measuring the "readiness of technology", the tendency for the individual to adopt state-of-the-art technology at home and at work.

The concept of technological readiness is widespread, especially in the field of business development, where research focuses on identifying market segments that are likely to adopt new technologies such as mobile data services and distance education (Caison et al. 2008).

Researchers found that the technology-ready model was effective in studying the tendency of respondents to adopt new technologies. While the scale of technological readiness has been widely used in academic and commercial contexts, a common concern reported by its users was that it was long, consisting of 36 objects (Parasuraman 2000).

A streamlined and updated version with 16 attributes was introduced by Parasuraman and Colby in 2015. The improved scale, called TRI 2.0, includes the overall Technology Readiness Index (TRI) as well as individual data on technology readiness.

The Technology Readiness Index (TRI) is determined by four dimensions of technological beliefs that affect a person's level of know-how (Elliott et al. 2008): *optimism* with a positive view of technology and a belief that it offers people increased control, flexibility and efficiency in their lives; *innovative*, a trend to be a pioneer of technology; *discomfort* with a lack of technology control and a sense of dependence on it; and *insecure* with distrust of technology and *scepticism* about its ability to function properly. Of these four dimensions, optimism and innovation are *drivers of technological readiness*, while discomfort and insecurity are *inhibitors* (Parasuraman 2000).

In relation to teachers' readiness to embrace ICT in education, Badri et al. (2014) defined the four dimensions as follows:

- *Optimism*, as the teacher who has a positive view of technology and a belief that it offers students and teachers increased control, flexibility and efficiency in their lives in the school and at home
- *Innovativeness*, as the teacher who tends to be a technology pioneer and thought teacher and leader both inside and outside of the classroom
- *Discomfort*, as the teacher who has a perceived lack of control over technology and a feeling of being overwhelmed by it
- *Insecurity*, as the teacher who has a distrust of technology and scepticism about its ability to work properly inside and outside of the classroom

The TRI 2.0 scale can be used to assess the technological readiness of employees, e.g. of the educators. Based on the results of TRI 2.0, Parasuraman and Colby (2015) also acquired a classification system that categorizes people into five technology adoption departments: the technologically oriented "explorer", the strongly involved "pioneer", the cool "sceptic", the careful "hesitant" and the technology-resistant "evader".

Although the TRI 2.0 scale is less than half the number of objects from TRI 1.0, there is interest in an even more concise version that could be used by researchers looking for a reliable measure of overall technological readiness. A ten-item version of the index was developed by the original TRI 1.0 and was used extensively before the introduction of TRI 2.0, which is a copyright-protected scale that requires written permission and authorization from authors.

The Technology Readiness Index (TRI 2.0) is a 16-item scale for measuring technological readiness, defined as "... people's tendency to adopt and use new technologies to achieve goals in their daily lives and work ... " (Parasuraman 2000: 308). Since the release of TRI 1.0, the pace of technological change has accelerated, with results such as high-speed Internet access, mobile commerce, social media and cloud computing. Technology has since revolutionized service delivery in almost all service categories.

The impact of technology in the service sector is already evident in the statistics presented in the United States in 1999 with the National Technology Readiness Survey (NTRS) (Parasuraman 2000). Data from the 1999 NTRS were used to develop, refine and validate TRI 1.0 (Parasuraman 2000). In the 2014's National Technology Readiness Survey (NTRS) where the TRI 2.0 scale was applied, the mean Technology Readiness Index was 3.2 (Parasuraman and Colby 2015).

Till now, the authors have provided academic licenses for the use of the TRI 1.0 scale to 127 researchers in 30 countries, where they have often been translated into local languages. Nearly a third (29%) of permits have been granted in the United States, but also in other countries such as Germany (9%), Malaysia (6%), Turkey (6%), the United Kingdom (6%), China (5%), India (5%), Brazil (4%), Canada (4%), the Philippines (4%) and South Africa (4%). Most of the studies concerned business and consumer environments (41%), business environments (30%) and educational content environments (29%). TRI 1.0 applications cover a variety of services, certifying the multiplier effect of technology in the service sector. Its applications then spread to government and non-profit services and more recently to healthcare (Parasuraman and Colby 2015).

The Technology Readiness Index (TRI 1.0) developed by Parasuraman was adapted to measure the technological readiness of public school teachers in Abu Dhabi, United Arab Emirates. The research study of Badri et al. (2014) aimed at a better understanding of the factors, mainly demographic factors, which affect this level of readiness. The results of the research study showed that Abu Dhabi's teachers are fragmented into five main groups, with the highest percentage being "laggards" and "explorers". The study sample consisted of 796 teachers in 105 different public schools. The overall level of technological readiness for teachers was 37,767. There were significant statistical differences in the sex of the teacher, the background (nationality) and the number of his students. Other variables such as teacher age, experience, education and job status had some effects (Badri et al. 2014).

Many studies have tried to examine the effect of demographic variables on the TRI. Research on technology acceptance suggests that a person's personality, as well as demographics, may affect acceptance (Parasuraman 2000; Lam et al. 2008; Son and Han 2011). In the context of education, the Technology Readiness Index is related to how prepared teachers are for a new technology or the integration of the technology to be used in the classroom (Badri et al. 2014). Significant results were observed in respondents regarding gender and the various dimensions of TRI or total TRI. In most cases and applications, male teachers had a statistically higher average of technological readiness than female teachers (Summak et al. 2010). Also, a study by Caison et al. (2008) for nursing students showed similar statistical differences in the effect on gender. In terms of age, some studies have found significant differences between younger and older respondents. Summak et al. (2010) found no significant differences in technological readiness in relation to the age and subject matter of teachers. Caison et al. (2008) found that the average technological readiness decreases with age. They found that nursing students in Canada over the age of 25 had a negative grade of technological readiness, while those under 25 had a positive score of technological readiness. Summak et al. (2010) [21] used the TRI 1.0 scale to assess the technological readiness of primary schools in Gaziantep, Turkey. They also looked at teachers' demographics to determine their impact on technological preparedness. The study sample consisted of 207 teachers in 11 different schools. The overall score of the teachers' technological readiness was moderate with the index being 2.96.

The review of the literature did not identify studies that investigate the effect of the position and employment relation of the teacher, the type of school unit he serves and his training in ICT in the index of technological readiness of teachers. Research studies on the Technology Readiness Index in educational systems, especially with the participation of teachers, were limited.

3 Research

3.1 Questions

This study addresses the following research questions:

1. What is the technology readiness level of Greece public school teachers?
2. What the relation between teachers' technology readiness level and their demographic variables?
3. What is the relation between the level of technology readiness and familiarization and utilization of GSN?

3.2 Method and Participants

This study aims to collect empirical data at a specific point in time in order to describe the nature of the existing conditions or to identify constants on the basis of which it is possible to compare the prevailing conditions (Babbie 2011; Robson 2010). Thus, it follows a quantitative approach based on empirical data gathered via an online questionnaire with close-ended questions. Sampling of a representative sample was used, the one examining current views (Creswell 2012), where sampling research is used to describe and identify views, attitudes and beliefs by collecting quantitative numerical data with questionnaires or interviews (Cohen et al. 2011; Creswell 2012).

The sampling strategy that, in general, is suitable for this type of research is the probability one, due to the size of this research (Creswell 2012; Robson 2010). But due to the difficulty of implementing a random sampling method in the present research study because of limitations in time and resources, the method of convenience sampling was chosen.

The target group was primary education teachers serving in public schools at Dodecanese Prefecture, Greece, during the academic year 2018–2019. The total population of the target group was 1.103 primary school teachers, and the convenience sample was finally 171 primary education teachers, consisting of 53 males (31%) and 118 females (69%). Ages between 28 and 36 years were the predominant ones at a rate of 60.8%, with the mean age of the participants being 36 years (S.D.: 8 years). In terms of their employment status, 73 (42.7%) worked as permanent employees, 96 (56.1%) as deputies and 2 (1.2%) as part-time employees.

Due to the limitations of the sampling method, the locality of the research and the final number of the respondents, results of this study are not generalizable to the whole population of primary education teachers in Greece.

For the collection of research data, an electronic questionnaire was forwarded by email to all primary schools in the Dodecanese Prefecture, informing, through a cover letter, the principals of the schools about the purpose and the aims of this survey research, ensuring also that the personal data of the participants will be processed in a safe manner, based on GDPR legislation. The survey remained open from February 19, 2019 to March 7, 2019.

3.3 Instrument

The TRI 2.0, a 16-item technological readiness scale (Parasuraman and Colby 2015), was used in this research study with the written permission of A. Parasuraman and Rockbridge Associates, Inc.

The TRI 2.0 measurement scale was translated into Greek. The reverse translation was used to check the similarity and consistency. Moreover, a pilot test of the survey was conducted in a sample of $N = 36$ primary teachers, to find and correct any grammatical, syntactical or expression errors.

The above scale consists of four dimensions (optimism, innovation, discomfort, insecurity) and each dimension of four items. The items of each dimension were randomized so that there was no positive or negative guidance in the respondents' answers. To calculate the total technological readiness score, the scores of discomfort and insecurity were initially reversed, due to their negative significance, subtracting from 6. Then, the average for the four dimensions was calculated (i.e. TRI 2.0 = [optimism + innovation + (6 – discomfort) + (6 – insecurity)]: 4).

Respondents were asked to rate their degree of agreement on a 5-point Likert scale for each item (i.e. 1, strongly disagree, to 5, strongly agree) and their degree of agreement on a 5-point Likert scale about the use of ICT in the educational process.

Also, they were asked to complete ten demographic questions (gender, age, studies, service position, employment relation, teaching experience, school type, teaching class, training in ICT and account in Greek School Network).

The Cronbach's reliability alpha (Tavakol and Dennick 2011) for the four dimensions (16 items) was 0.778.

3.4 Data Processing

The TRI (Technology Readiness Index) identifies four dimensions of technology belief that impact a teacher's level of techno-readiness (optimism, innovation, discomfort and insecurity). The current study used a 16-item version (TRI 2.0) (Parasuraman and Colby 2015).

After collecting the research data, their quantitative analysis followed. Using the SPSS 23 statistical package and through the descriptive analysis, the frequencies and percentage distributions were recorded. Descriptive statistics (means and standard deviations) were obtained for all items and dimensions in the survey. The inductive analysis of the research data was done on variables related to the research hypotheses.

The selection and application of the appropriate statistical criteria were done according to the literature (Rea and Parker 2014; Joseph et al. 2014). Specifically, both parametric and nonparametric tests were performed depending on whether the values of the Technology Readiness Index are normally or not distributed to the respective demographic variables (Rea and Parker 2014).

An *independent samples t-test* was conducted to compare the levels of technology readiness of teachers in terms of gender. To test differences between groups (in terms of gender, age, studies, job position, employment relation, teaching experience, school type, teaching class, training in ICT, an account in Greek School Network), the nonparametric criterion *Kruskal-Wallis test* was used. In order to find whether and to what extent there was a correlation between the TRI score and the degree of ICT use in the educational process and the degree of use of GSN's services/digital tools, we used the nonparametric *Spearman's rho criterion*, because there was no linear relation between our variables, as the examination of the scatter plot showed several deviating values. Also, *one-way ANOVA* test was used to explore relations between the dimensions of technology readiness and variables of educational level, ICT training and account at GSN.

4 Results

Table 1 shows the profile characteristics of the participants in this study. 69% of the respondents were female (n = 118), and 31% were male (n = 93), while 60.8% of the respondents were between 28 and 36 years old. 19.9% of teachers were over 44 years old. Most of the teachers acquire a state certification in ICT skills, with 36.2% having an A level (i.e. entry level) certificate and 39.2% having a B level (i.e. advance level) certificate. Moreover, 53.8% of the teachers have been registered for an account at GSN.

Mean scores and standard deviations of each TRI dimension are shown in Table 2. Optimism was rated with the highest mean score of 4.02. The next highest dimension was innovation (3.30). These are the drivers of TRI. It means that the optimism and innovation dimensions positively affect TRI. Teachers' optimism levels were found to be higher than their innovation. The discomfort and insecurity dimensions, inhibitors of TRI, provided mean values of 3.23 and 2.44, respectively. The ranking of the means of the TRI dimensions is consistent with other studies conducted in the education context (Badri et al. 2014; Summak et al. 2010). The mean of all dimensions of TRI (overall) was 3.252 with a mean standard deviation of 0.49.

An independent samples t-test was conducted to compare the level of technology readiness of teachers in terms of gender. As shown in Table 3, there was a significant difference in the scores for female and male teachers for the two dimensions of discomfort $t(169) = -2.825$, $p = 0.005$ and insecurity $t(169) = -2.572$, $p = 0.011$. Female teachers scored a mean of 3.364 for discomfort and 2.536 for insecurity. Male teachers scored a mean of 2.957 for discomfort and 2.235 for insecurity.

Table 1 Demographic characteristics of the participants

	Frequency	Percent (%)
Gender		
Male	53	31.0
Female	118	69.0
Age		
≤28	15	8.8
28–36	104	60.8
37–44	18	10.5
≥44	34	19.9
ICT training		
A level	62	36.3
B level	67	39.2
Trainer in ICT	5	2.9
None	22	12.9
Other	15	8.8
Account in GSN		
Yes	92	53.8
No	69	40.4
Desire to acquire	10	5.8

Note: $N = 171$

Table 2 Means and standard deviations on the TRI 2.0 dimensions

Dimension	Mean	St. d.
Optimism	4.02	0.69
Innovation	3.30	0.92
Discomfort	3.23	0.88
Insecurity	2.44	0.71
TRI (overall)	3.25	0.49

Table 3 Independent samples t-test (TRI 2.0 and gender)

Dimension	*T*	Sig (2-tailed)	Mean Diff.	Std. Er. Diff.
Optimism	−0.235	0.814	−0.02706	0.11492
Innovation	1.851	0.066	0.28130	0.15196
Discomfort	−2.825	0.005	−0.40686	0.14400
Insecurity	−2.572	0.011	−0.30017	0.11672
TRI(overall)	−1.388	0.167	−0.11409	0.08220

Note: $N = 171$, $p < 0.05$

There was no significant difference regarding optimism, innovation and overall TRI ($p = 0.05$). Results do not confront with other studies, where male teachers show more technology readiness than female teachers (Badri et al. 2014; Summak et al. 2010; Lee et al. 2009).

Kruskal-Wallis test was used to explore relations between the dimensions of technology readiness and demographic variables. As shown in Table 4, no significant relation was found between the four dimensions of technology readiness and

Table 4 Kruskal-Wallis test (TRI 2.0 and other demographic variables)

Demographic variable	Chi-Square	df	Asymp. Sig.
Age	2.847	3	0.416
Educational level	11.244	5	0.047
Service position	1.449	2	0.485
Employment relation	3.719	2	0.156
Teaching experience	2.552	5	0.758
School type	8.829	7	0.265
Teaching class	5.563	8	0.696
ICT training	10.532	4	0.032
Account at GSN	8.350	2	0.015

Note: $N = 171$, $p < 0.05$

Table 5 One-way ANOVA (TRI 2.0 and educational level, ICT training, account at GSN)

	Educational level	ICT training	Account at GSN			
Dimension	F	Sig	F	Sig	F	Sig
Optimism	3.078	0.011	2.787	0.028	4.137	0.018
Innovation	1.575	0.170	4.852	0.001	5.595	0.004
Discomfort	0.374	0.866	0.690	0.600	0.550	0.578
Insecurity	1.050	0.390	3.136	0.016	2.582	0.079
TRI (overall)	2.802	0.019	3.383	0.011	5.756	0.004

Note: $N = 171$, $p < 0.05$

these variables, except the variables “Educational level” H(5) = 11.244, $p = 0.047$”, ICT training” H(4) = 10.532, $p = 0.032$ and “Account at GSN”, H(2) = 8.350, $p = 0.015$.

As shown in Table 5, one-way ANOVA was used to explore relations between the dimensions of technology readiness and variables of educational level, ICT training and account at GSN. The teachers had to respond with five alternative choices: precollege diploma, college degree, second college degree, master’s degree and PhD degree. The mean scores for overall TRI for the five-teacher categories in corresponding order were 2.991, 3.202, 3.227, 3.353 and 3.384.

The level of education that a teacher has attained had a significant effect on dimension of optimism and overall TRI. Badri et al. (2014) and Lee et al. (2009) also found significant differences regarding level of education. Regarding ICT training, significant difference was found between the three dimensions of technology readiness (optimism, innovation, insecurity) and this variable.

In addition, the scores of the overall TRI showed significant differences. Teachers responded with five alternative choices: A level, B level, ICT trainer, other training and none training. ICT training had significant effect on TRI scores. The mean scores for overall TRI for the five-teacher categories in corresponding order were 3.164, 3.303, 3.878, 3.125 and 3.372. The level of ICT training that a teacher has attained had a significant effect on optimism dimension (3.871, 4.041, 4.800, 4.193, 4.066), innovation dimension (3.048, 3.507, 4.550, 3.227, 3.116) and insecurity

Table 6 Correlation between TRI 2.0 and actual use, familiarity and potential utilization of GSN's services/digital tools

Degree of	Sig (2-tailed)	Correlation coefficient	Degree of correlation
Actual use	0.202**	0.134	Not significant
Familiarity	0.000**	0.364	Low
Potential utilization	0.217*	0.130	Not significant

Note: $a = 92$, *$p < 0.05$, **$p < 0.01$. Degree of correlation: <= [+ − 0.29] non-existent correlation, [+ − 0.30] – [+ − 0.49] low correlation, [+ − 0.50] – [+ − 0.69] moderate correlation, [+ − 0.70] – [+ − 0.79] high correlation, [+ − 0.80] – [+ − 0.99] very high correlation

dimension (2.504, 2.421, 2.800, 2.034, 2.766). Also, teachers with the highest ICT training showed the highest insecurity level.

The account at GSN has a significant effect on two dimensions of TRI $f(2{,}168) = 4.137$, $p = 0.018$ for optimism; $f(2{,}168) = 5.595$, $p = 0.004$ for innovation; and $f(2{,}168) = 5.756$, $p = 0.004$ for overall TRI.

If we divide teachers into "teachers have an account at GSN", "teachers do not have an account at GSN" and "teachers desire to acquire an account at GSN", we note the following corresponding mean scores for the two dimensions of TRI and overall TRI which have significant differences: 4.097, 3.865 and 4.425 for optimism; 3.505, 3.025 and 3.325 for innovation; and 3.331, 3.109 and 3.521 for overall TRI, respectively.

For discomfort and insecurity, mean scores are 3.220, 3.221 and 3.525 and 2.497, 2.318 and 2.800, respectively. These means scores showed no significant differences. Teachers who were familiar with and had access to the GSN's services/digital tools formed a higher Technology Readiness Index (3.311) compared to those who did not have an account at GSN (3.161). This difference is not statistically significant.

As shown in Table 6, Spearman's rho parameter criterion was used to explore relations between TRI and actual use, familiarity and potential utilization of GSN's services/digital tools. TRI is not related to the actual use rs(92) = 0.134, $p = 0.202$ and potential utilization of GSN's services/digital tools rs(92) = 0.130, $p = 0.217$. Only the degree of the familiarity with the GSN's services/digital tools rs(92) = 0.364, p = 0.000 is related to the TRI, but with a low correlation.

Finally, as shown in Table 7, Spearman's rho parameter criterion was used to explore relations between TRI and use of ICT in teaching, use of portable devices in teaching and incorporating BYOD practice into teaching. TRI is directly related to the use of ICT in teaching with a moderate degree of correlation rs(171) = 0.505, $p = 0.000$.

In addition, both the degree of the use of portable devices during teaching rs(171) = 0.353, $p = 0.000$ and the integration of BYOD rs(171) = 0.316, $p = 0.000$ related to the TRI, but with a low correlation.

Table 7 Correlation between TRI 2.0 and use of ICT in the educational process

ICT in the educational process	Sig (2-tailed)	Correlation coefficient	Degree of correlation
Use of ICT in teaching	0.000	0.505	Moderate
Use of portable devices in teaching	0.000	0.353	Low
Incorporating BYOD practice into teaching	0.000	0.316	Low

Note: $a = 171$, $p < 0.01$. Degree of correlation: <= [+ − 0.29] non-existent correlation, [+ − 0.30] – [+ − 0.49] low correlation, [+ − 0.50] – [+ − 0.69] moderate correlation, [+ − 0.70] – [+ − 0.79] high correlation, [+ − 0.80] – [+ − 0.99] very high correlation

5 Discussion

This research aimed at measuring Greek public school teachers' technology readiness by using TRI, a scale consisting of four dimensions, i.e. optimism, innovativeness, discomfort and insecurity.

For Greek public schools, teachers' optimism level was higher than their innovativeness, and the mean value of the insecurity dimension was lower than the discomfort dimension. This result is not consistent with results obtained by Summak et al. (2010). TRI results from other empirical research, not related to education, provided results consistent with the current research regarding the rank magnitude of TRI scores for each of the dimensions (Badri et al. 2014; Summak et al. 2010). The TRI score in Summak et al. (2010) for Turkish teachers was 2.96, while the TRI score for Abu Dhabi teachers (Badri et al. 2014) was 3.28.

Optimism and innovativeness are drivers of technology readiness. The highest score was related to teacher optimism. For teachers, optimism relates to a positive view about technology and a belief that technology offers teachers increased control, flexibility and efficiency in life (Parasuraman 2000). Insecurity and discomfort are inhibitors of TR. Both had the lowest scores. Insecurity involves the distrust of technology for security and privacy reasons (Parasuraman 2000). The insecurity dimension focuses on specific aspects of technology-based transactions, rather than lack of control over new technology in general (Son and Han 2011).

With regard to teachers and TRI and other demographic variables, it was possible to compare the results of this study with previous research as few researchers (Badri et al. 2014; Summak et al. 2010) had conducted related research on education. The lack of previous research was observed with ICT training and employment relation between teachers.

Regarding teachers' gender and their attitudes to TR, significant differences were not observed. Similar studies didn't find any differences between gender as well (Ramayah et al. 2003). However, other studies confirmed that male teachers demonstrated a higher overall technology readiness score than female teachers (Badri et al. 2014; Summak et al. 2010; Lee et al. 2009).

In terms of the age of teachers, there was not a significant difference between the technology readiness of teachers regarding overall TR. Some studies reported that there is no significant difference between attitudes about TRI and age (Badri et al. 2014; Summak et al. 2010).

The level of education that a teacher has attained had a significant effect on dimension of optimism and overall TRI. The results of current study are consistent with the results of other studies conducted in education (Badri et al. 2014; Lee et al. 2009).

ICT training has significant effect on TRI scores. The level of ICT training that a teacher has attained had a significant effect on optimism, innovation and insecurity dimension. Teachers with the highest ICT training showed the most insecurity.

The account at GSN has a significant effect on two dimensions of TRI (optimism and innovation) and for overall TRI. The low degree of correlation between the TRI with the degree of familiarity with the GSN's services/digital tools and the non-existent degree of correlation with the degree of actual use of the GSN's services/digital tools indicates that the teacher's technological readiness level is not related to the familiarization and actual use of GSN's services/digital tools. Teachers who were familiar with and had access to the GSN's services/digital tools formed a higher Technology Readiness Index (3.311) compared to those who did not have an account at GSN (3.161). This difference is not statistically significant.

Finally, there were not significant differences regarding service position, employment relation, teaching experience, school type and teaching class on overall TRI.

6 Conclusions

This study initialized Parasuraman and Colby (2015) research on technology readiness, for the first time in Greece, with a focus on the educational sector and showed that Greek public school teachers' technology readiness level was relatively moderate and teachers who belong in the discomfort zone of the TRI should be subjects of further training from the state.

Although results are not generalizable due to the sampling limitations, they can inform educational stakeholders at various levels regarding the planning of educational interventions and initiatives concerning Teacher Professional Development (TPD) programs on digital literacies and actual pedagogical use of ICT in the classroom.

Thus, future initiatives should focus on this issue by utilizing large-scale research efforts (for instance, national level, secondary education teachers, parents) and mixed data collection and analysis methods.

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Augmented Reality Books: What Student Teachers Believe About Their Use in Teaching

George Koutromanos and Eleni Mavromatidou

1 Introduction

Along with the development of mobile technologies in recent years, Augmented Reality (AR) has been increasingly employed in formal and informal environments (Garzón and Acevedo 2019; Ibáñez and Delgado-Kloos 2018). AR allows users to interact with digital or virtual objects integrated into a real-world environment (Azuma et al. 2001). The educational advantages of AR have been discussed extensively in the literature (Garzón and Acevedo 2019; Ibáñez and Delgado-Kloos 2018). One emerging trend of AR in education is AR books. According to Danaei et al. (2020), in AR books, digital content is represented in different formats (i.e. 3D objects, images, sound, video) and experienced using PC, mobile (i.e. smartphone, tablet) or wearable devices (e.g. head-mounted display).

The educational affordances of AR have prompted developers, educators and researchers to design and evaluate numerous AR books and textbook activities in various subjects, such as History (Santana-Mancilla et al. 2012), Mathematics (Corrêa 2014), Physics (Yang et al. 2013), Environmental Education (Lin et al. 2011) and Language (Danaei et al. 2020; Koutromanos and Sofos 2018). Most of these studies indicate that learners' interaction with AR books and the execution of interactive activities within them contributed to positive attitudes towards learning (e.g. Lin et al. 2011), in addition to positively influencing learning effectiveness (Danaei et al. 2020; Koutromanos and Sofos 2018; Yang et al. 2013).

Due to AR books' multiple affordances, an increase in their use for educational purposes in both private and public schools is expected in the coming years. In addition, nowadays AR authoring tools which enable creating AR experiences

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without programming knowledge are available. However, this innovative technology is insufficient in itself. The successful introduction of an advanced technology in the classroom, such as the use of AR books, depends on the teachers who implement the technology in practice. According to Fullan (2015), "educational change depends on what teachers do and think" (p. 115). More specifically, every innovation requires teachers to change in three dimensions: the possible use of new materials, the possible use of new teaching approaches and the changes in their beliefs and attitudes. In this sense, over the last four decades, a number of studies have focused on the psychological factors that influenced the uptake of ICT in schools, such as attitudes and beliefs. Although the research community has studied various aspects of AR books (e.g. design and development, effect on learning), no research has been conducted toward understanding student teachers' beliefs about using AR books in their future teaching.

The aim of this study was to explore student teachers' beliefs regarding their decision to use AR books in their future teaching. The in-depth examination of these beliefs could allow the identification of the factors that may influence the intentions of student teachers in primary schools to adopt AR books in the years to come. To this end, the current study addressed the following research questions:

1. What are student teachers' intentions regarding the use of AR books in their future teaching?
2. What is student teachers' perceived ease of use regarding using AR books in their future teaching?
3. What are student teachers' behavioural, normative and control beliefs regarding their intention to use AR books in their teaching?
4. What relative advantage do student teachers believe AR books can offer to their future teaching compared to unaugmented books?

2 Characteristics of Augmented Reality Books

As a result of their attractiveness, interactivity, multimodality and contextuality, AR books can afford pedagogical benefits, which are not feasible with the use of print books. The literature includes many examples of AR books, which have been augmented with a different type of content and used in real educational settings, such as AR storybooks containing animations, sound effects and oral narration (Danaei et al. 2020; Dünser and Hornecker 2007), AR science books with 3D animated models or supplementary digital materials (Dünser et al. 2012; Yang et al. 2013), as well as video augmented history books (e.g. Santana-Mancilla et al. 2012). The main core elements of AR books are subsequently discussed.

A very important feature of AR books is that they allow the user to interact with the augmented objects. These objects are usually 3D graphics (Azuma et al. 2001), video, images, animation, text and sound (Dunleavy 2014). The type of augmentation determines the degree of data representation, as well as the degree of interactivity with the student (Corrêa 2014; Martín-Gutiérrez et al. 2015). Furthermore, the quality of the technical features of the augmented objects, their number, and the manner in which they are laid out on the page of an AR book can positively or negatively affect the book's usability (Corrêa 2014). Another important element is the precise rendering and reliability of the augmented object (Azuma et al. 2001), as its accurate view can enable users' realistic and natural interaction with it (Rambli et al. 2013).

Another characteristic of AR books is the user's degree of interactivity with the augmented objects. It is argued that a greater degree of interactivity can contribute to increased motivation among students regarding learning, as well as greater student involvement in the learning process (Dünser et al. 2012). In first-generation AR books, interactivity was essentially absent and the user simply viewed or listened to the augmented object. Today, AR books offer a different type of interactivity, such as the ability to rotate or adjust the size of the augmented object, movement and control both within the book and outside of it. The type, technical quality, quantity, and layout of the augmented objects, combined with the degree of interactivity, contributes to the user's immersion and feeling of a sense of realism regarding the object's coexistence with the book's content in real-world settings (Di Serio et al. 2013). From a pedagogical standpoint, augmented objects (quality, quantity, layout) combined with interactivity could offer added value to the book's content compared to traditional teaching (Dünser and Hornecker 2007; Rambli et al. 2012; Tomi and Rambli 2013).

Finally, a basic characteristic of AR books is their content sharing ability, which means the ability to share augmented content with other users through known social media platforms or other applications and devices (e.g. projectors, PC computers, smart glasses). This feature was not available in AR books that were used in studies up until today, as well as the first commercial AR books, but is now possible thanks to technological advances (Dunleavy and Dede 2014).

3 Theoretical Framework

The Technology Acceptance Model (TAM) and the Theory of Planned Behaviour (TPB) have been widely used in education to explore teachers' beliefs regarding the use of ICT in teaching. The TAM was adopted from the Theory of Reasoned Action (TRA) (Ajzen and Fishbein 1980) and theorizes that two beliefs, perceived ease of use and perceived usefulness, are two key determinants of technology adoption. Perceived usefulness is defined as "*the degree to which a person believes that using a particular system would enhance his or her job performance*" (Davis 1989, p. 320). Perceived ease of use is defined as "*the degree to which a person believes that using a particular system would be free from effort*" (Davis 1989, p. 320). Both these variables influence the attitude of individuals towards the use of a particular technology, while attitudes towards use and perceived usefulness influence the individual's intention to use the technology. Intention, in turn, predicts users' actual usage behaviour. Results from previous meta-analysis studies show that TAM is still a valid model (e.g. Koutromanos et al. 2015; Scherer et al. 2019). The variables of TAM (i.e. perceived usefulness, perceived ease of use) remain the core for a number of revised and extended TAMs (e.g. Scherer et al. 2019).

The TPB is a model that was expanded from the TRA (Ajzen 1991). According to the TPB, attitude towards the behaviour, subjective norm and perceived behavioural control are important predictors of behavioural intention. In turn, intention influences behaviour. Attitudes are overall evaluations of the behaviour as positive or negative for the individual, while subjective norms are general perceptions of social pressure to perform or not to perform a particular behaviour. Perceived behavioural control is the new variable in the TPB and refers to individuals' perceptions of their ability to perform a particular behaviour. TPB includes three types of beliefs: behavioural, normative and control beliefs. According to Ajzen (2019), behavioural beliefs are the subjective probability that the behaviour will produce a given outcome or experience. Normative beliefs refer to the perceived behavioural expectations of significant others. Control beliefs are perceptions of obstacles, impediments, skills, resources and opportunities that may inhibit or facilitate the performance of the behaviour. Behavioural, normative and control beliefs "*are assumed to provide the cognitive and affective foundations for attitudes, subjective norms, and perceptions of behavioural control*" (Ajzen 1991, p. 7). "*By measuring beliefs, we can, theoretically, gain insight into the underlying cognitive foundation, i.e. we can explore why people hold certain attitudes, subjective norms, and perceptions of behavioural control*" (ibid. p. 8).

To sum up, following the conceptual framework presented above, we used specific variables from the TAM and TPB models. First, we kept the following constructs from the TAM model: perceived ease of use and behavioural intention. Prior technology acceptance research has found that belief regarding ease of use is the most important determinant for the usage of technology among non-experienced teachers (Koutromanos et al. 2015). In this study, student teachers, who lack experience, may present a strong intention to use AR books in their future classrooms if they believe that these books provide ease of use. Second, we used behavioural, normative and control beliefs from the TPB model. Our focus was to place greater attention on the collection of qualitative data regarding these beliefs rather than verify statistical relationships or investigate determinants between the variables of acceptance models. In addition to the above, the variable of perceived relative advantage from the Diffusion of Innovation Theory was used in this study (Rogers 2003). According to Jeong et al. (2017), this variable "*refers to the degree to which an innovation is seen as better than the idea, program, or product it replaces . . . The greater the perceived relative advantage of an innovation, the more rapid its rate of innovation adoption will be*" (p. 402). Therefore, in this study, we used this variable in order to explore student teachers' perceived relative advantage of AR books compared to physical books.

4 Student Teachers' Acceptance of Technology

In this section, we present the most relevant studies which have focused on examining pre-service teachers' attitudes and beliefs across different ICT applications. For instance, Teo et al. (2009) investigated pre-service teachers' future intention to use technology based on the variables of the TAM. The results showed perceived ease of use, perceived usefulness, and attitudes to be significant determinants of pre-service teachers' behavioural intention. In another study, Teo (2009) found that perceived usefulness, attitude towards computer use, and computer self-efficacy have a direct effect on pre-service teachers' intention to use technology, whereas perceived ease of use, technological complexity, and facilitating conditions affect pre-service teachers' intention indirectly. In a study on pre-service teachers' intention to use technology, Teo and Noyes (2011) found that perceived enjoyment was a significant predictor of perceived usefulness, perceived ease of use, and intention to use technology.

Wong et al. (2013) researched student teachers' behavioural intention to use technology in teaching and learning, using the TAM model. The results revealed that perceived usefulness significantly influences attitude towards computer use and behavioural intention. In addition, perceived ease of use significantly influences perceived usefulness, and intention is found to be influenced by the attitude towards computer use. Similarly, Koutromanos et al. (2015) investigated the factors that influence student teachers' intention to use a spatial hypermedia application in their teaching, and the results indicated that all components of the TAM predict their intention. Sanchez-Prieto et al. (2017) used the TAM as well as the constructs of self-efficacy and mobile anxiety in order to examine pre-service teachers' intention to use mobile devices in their future teaching practice. They found that the stronger relationships were those established between perceived usefulness and behavioural intention, perceived ease of use and perceived usefulness, and self-efficacy and perceived ease of use.

Smarkola (2008), in her qualitative study, used the TAM and TPB to examine beliefs contributing to student teachers' and experienced teachers' intentions to use computer applications in their curricula. She identified four themes that were found to have influenced student teachers' intentions; namely, "The Value of Computers to Teaching and Learning," "Make Way for Learning Through the Internet," "Wanted – Computer Training in First Year Teaching" and "High Personal Computer Confidence." Using the TPB as their research framework, Sadaf et al. (2012) conducted a qualitative study to explore pre-service teachers' behavioural, normative, and control beliefs regarding their intentions to use Web 2.0 technologies in their future classrooms. They found that the majority of student teachers reported very positive beliefs towards Web 2.0 use in their future teaching. The most commonly expressed behavioural beliefs were "engagement with content," "enhanced learning," "enrich learning experience through innovative tools," "help facilitate understanding of material/concepts," "easy to use and cater to the needs of different learning styles." Among those rated as most likely to approve of the use of Web 2.0 were students, administrators, colleagues and parents. The control beliefs identified in their study can be divided into those related to “high self-efficacy in personal use,” “access to learning outside the classroom” and “restricted access to computers and internet.”

5 Research Methodology

5.1 Participants

This study used a non-random sampling technique (i.e. convenience sampling) to collect data. The subjects who volunteered to participate in this study were 246 student teachers from the Department of Education of the National and Kapodistrian University of Athens. They were enrolled in a course on “ICT in Education,” which was one of the core curriculum courses required for all undergraduates. Among the 246 student teachers, 40 (16.3%) were males and 206 (83.7%) were females. Their average age was 20.37 ($SD = 0.963$) years old.

5.2 Procedure

This study was carried out during the 2018–2019 academic year in three phases. In Phase 1, student teachers participated in a computer laboratory course in groups of 20, regarding the affordances of AR and the tools available to develop applications. In Phase 2, the sample groups interacted with available commercial AR books, as well as textbooks that had some of their units augmented with digital content by the research team. In Phase 3, student teachers completed the research questionnaire, which was composed of open-ended and closed-ended questions, and which was formulated based on the theoretical framework of the TPB and TAM. The duration of all three phases for each student lasted approximately 2.30 h.

5.3 Questionnaire

A three-part questionnaire was used for collecting quantitative and qualitative data. In the first part of the questionnaire, student teachers were asked to provide demographic information (gender, age), while in the second part, there were four items regarding intention and three regarding perceived ease of use. The four items for intention were adapted from Yang et al. (2016) (i.e. Using AR books in teaching is worthwhile, I intend to use AR books in my teaching in the future, I predict I would use AR books in my teaching in the future, I recommend others – i.e. student teachers and in-service teachers – to use AR books). The three items for perceived ease of use were adapted from Davis (1989) (i.e. I find the AR books easy to use, My interaction with AR books is clear and understandable, It is easy for me to become skilful at using AR books). Each item was measured on a 5-point Likert scale with values ranging from 1 (strongly disagree) to 5 (strongly agree).

The third part of the questionnaire contained open-ended questions that asked student teachers to list their beliefs regarding the use of AR books in their future classrooms. First, they were asked to list: (a) the advantages and disadvantages of using AR books in their future classrooms (behavioural beliefs), (b) the persons or groups who would approve or disapprove of AR books' use in their future classrooms (normative beliefs) and (c) the factors or circumstances that make it easier or more difficult for them to use AR in their future classrooms (control beliefs). These questions were adapted from the TPB (Ajzen 2019). Second, student teachers were asked to list the perceived relative advantages of AR books compared to standard print books. This question was based on the Diffusion of Innovation Theory (Rogers 2003).

A pilot version of the questionnaire was developed and distributed to 10 student teachers to get their suggestions and clarifications. In addition, the questionnaire was reviewed by three experts in ICT in education and adjusted accordingly.

5.4 Analysis Method

Data analysis from the closed-ended questions was conducted on SPSS (version 25). Data was analysed using descriptive statistics (means and standard deviation analysis). The data from the open-ended questions were codified into thematic categories by two researchers in ICT in Education.

6 Results

6.1 Intention and Perceived Ease of Use

Table 1 presents descriptive statistics of the two constructs used in this study. Results of this table indicate that student teachers responded positively to intention to use AR books in their future classrooms and to ease of use.

Table 1 Descriptive statistics and Cronbach's Alpha of behavioural intention and perceived ease of use

Constructs	Cronbach's alpha	Mean	Standard deviation
Ease of use	0.772	4.08	0.641
Behavioural intention	0.896	4.07	0.700

6.2 Behavioural Beliefs

The results of the open-ended questions revealed the most commonly expressed behavioural beliefs concerning the integration of AR books in teaching. Specifically, the most widely noted perceived advantages were that AR books have the potential to attract pupils' interest (66%) and create pleasant feelings by making the lessons fun and vivid (63%). Moreover, a large proportion of the participants believed that the educational use of AR books can facilitate the understanding of concepts (35%), offer immediate access to information and visualization without spatiotemporal limitations (34%), enhance motivation and subsequently trigger pupils' active participation in the educational process (33%). The potential of AR books to contribute to the improvement of learning outcomes by enabling knowledge acquisition and maintenance was also recognized by student teachers (27%). Smaller proportions of the student teachers referred to AR books' innovativeness (19%), their consistency with student-centred approaches, such as constructive and experiential learning (17%), their interactivity (13%), as well as their ease of use, learnability and operability, which could facilitate pupils' familiarity with technology (10%). Some representative answers were the following:

> I strongly believe that the use of AR books can make my teaching fun and innovative. My pupils' interest will remain undiminished. The visual contact with the teaching objects could contribute to the achievement of quick, easy, and successful understanding. (Student teacher 2)

> The children will probably retain much knowledge because AR books can capture their attention. Since most of them are familiar with technology from a young age, the interaction with augmented books will seem easy and natural. (Student teacher 7)

> The combination of knowledge provision with multiple stimuli will capture my pupils' interest and curiosity and might improve their memory skills, thus making my teaching effective. (Student teacher 54)

> . . . AR books' use can be conducive to knowledge acquisition by many types of learners, such as visual, auditory, and kinesthetic. (Student teacher 120)

> The use of these books will make my teaching student-centered. The children can be encouraged to navigate through the provided virtual objects autonomously and explore new knowledge on their own. (Student teacher 59)

> . . . Pupils can see in detail things they would not be able to see in real life. (Student teacher 199)

Regarding the emergence of disadvantages, some student teachers expressed their concerns about the possibility of classroom disruption (26%) and pupils' digression from learning objectives due to a possible overfocus on the technology (17%). In addition, student teachers noted that the implementation of AR books might be a time-consuming process (15%) and might lead to a gradual devaluation of reading "unaugmented" print textbooks (13%). The following answers were selected as typical examples of these views:

> I think that pupils would focus on the fun aspect of these books and attempt to discover their affordances, rather than acquire new conceptual knowledge. (Student teacher 31)

> Children might show a strong preference for these books and lose their interest when it comes to reading print books. (Student teacher 211)

Another concern mentioned was the high cost of the required equipment (13%). Within this framework, concerns over the possible expansion of the digital divide were highlighted. For example, one participant (Student teacher 126) stated that "not all pupils will be able to have access to AR books at home because of a possible lack of equipment. In this case, pupils who do not have the necessary technological means would feel inferior to those who do. Children should be provided with equal education opportunities".

This concern was followed by references to a possible technology addiction, which could cause social alienation (9%). As one participant mentioned, "the uncontrolled use of AR books could be linked with technology addiction and an increase in passivity or social withdrawal" (Student teacher 169). The devaluing of traditional teacher-centred approaches to learning (7%) and the negative impact on pupils' creative, reading or writing skills (4%) were also perceived as possible disadvantages of AR books' incorporation in teaching:

> The excessive use of new technologies is accompanied by an increased risk of converting traditional teaching methods into a totally boring and dull process for the pupils. (Student teacher 6)

> Teachers' role might be devalued, since technological tools would assume their role. (Student teacher 237)

> AR books might restrict pupils' imagination, since they are supplied with specific ready-to-consume images. As a result, they might not be able to utilize their creativity so as to construct their own personal images. (Student teacher 119)

6.3 Normative Beliefs

The categorization of the questionnaire data regarding student teachers' normative beliefs revealed the important others who may exert an influence both for and against AR books' integration in teaching. The most frequently reported positive influence on student teachers' intention to use AR books were their future pupils (71%). According to one participant, "children love to use new technologies" (Student teacher 12), while another mentioned that "children feel boredom because of teaching routines" and that "they would surely support the implementation of a different approach to learning" (Student teacher 145).

The participants also believed that young teachers are more likely to support them in their decision to use AR books due to the fact that new generations of teachers are likely more technologically literate and support innovation (67%). More specifically, the reasons mentioned regarding why younger teachers are more likely to support AR books' use were that they "have more technological knowledge"

(Student teacher 110), “are more informed about technology’s positive impact on learning” (Student teacher 173), “are open to new challenges” (Student teacher 216) and “often adopt progressive attitudes toward teaching methods” (Student teacher 102).

Smaller proportions of the student teachers regarded parents (37%) and school administrators (34%) as supportive influences. For example, one participant noted that “parents who are informed about the benefits of the educational use of technology would be positive towards AR books” (Student teacher 148) and another that “school administrators would surely be supportive when it comes to utilizing innovative teaching tools” (Student teacher 30).

In contrast, the participants believed that elderly teachers are more likely to be unsupportive towards their decision to use AR books, as they are expected to be more technologically illiterate and support intensively traditional methods (56%). As one student reported, “elderly teachers would probably oppose them, because handling the technology might be difficult for them” (Student teacher 36). Another one stated the view that “elderly teachers often defend outdated teaching methods” (Student teacher 205). Elderly teachers were followed by parents (37%) and school administrators (34%). Some representative statements which explain the reasons for their possible opposition were the following:

> Parents might regard AR books as amusement tools rather than teaching tools. (Student teacher 31)

> Maybe parents would not like their children to be attached to technology at such young ages. (Student teacher 48)

> I believe there are parents who cannot afford to obtain the necessary compatible devices. (Student teacher 4)

> Taking into consideration the curriculum I have to teach, I suppose that school administrators would not support me in the use of AR books because they would consider it a waste of time. (Student teacher 29)

> School administrators would be unsupportive due to the lack of the needed technical infrastructure and its relatively high cost. (Student teacher 188)

Furthermore, a limited number of student teachers (11%) believed that government representatives might also be negatively disposed towards the utilization of AR books due to financial issues. According to one of them, “the purchase of portable devices or a high-speed internet connection might not be funded by the government” (Student teacher 236).

6.4 Control Beliefs

The questionnaire data analysis concerning the control factors that can facilitate or impede the integration of AR books in teaching revealed that the majority of the participants (71%) regarded accessibility of the required technology (e.g.

mobile devices, internet connection) as the most substantial facilitative factor in the adoption of AR books. Teachers' prior technological knowledge (58%) and the pupils' response, which – according to our research sample – depends on their familiarity with technology, their technological skills, and their willingness to participate (33%) were considered of essential importance. Student teachers also believed that teachers' willingness, co-operation and peer support (18%), as well as the provision of training courses or the availability of technical assistance (18%) can play a fundamental role in facilitating the integration of AR books. More infrequently, reported facilitative factors were the abundance of AR books focused on pedagogical aims (7%), teachers' capacities (e.g. imagination, creativity, organizational skills) or self-confidence (6%), and the anticipated cost reduction due to technological evolution (5%). For example, the following opinions were expressed:

> The integration of AR books would definitely be easier if there were plenty of educational AR books and if schools provided me all the necessary technological means to achieve my instructional goals, such as tablets. I would also be interested in attending training courses so as to be able to introduce these books to my pupils properly and responsibly, as well as use them as effectively as possible. (Student teacher 26)

> Two essential conditions for the implementation of AR books would be teachers' technical aptitude and the existence of a group of expert educators who will provide me with the necessary technical guidance when needed. (Student teacher 67)

> ... Being familiar with technology is important but not enough. I need to have adequate knowledge regarding AR books so as to properly utilize them in classroom. (Student teacher 224)

> The existence of peer-support among teachers is really important for the effective integration of AR books in teaching. (Student teacher 30)

> AR books' use strongly depends on teachers' willingness and interest in this specific technology. (Student teacher 82)

> Teachers' creative and organizational skills might play a significant role in the introduction of any new learning tool. (Student teacher 133)

From the opposing point of view, the most frequently reported factor limiting the integration of AR books in teaching was the restricted access to technological infrastructure (e.g. devices, internet) either at school or at home (81%). For example, one participant conveyed this view: "As far as I am aware, most schools lack accessibility to basic technological resources. Thus, I am convinced that I would not be able to secure a tablet for each pupil. I am also doubtful about whether my future pupils could have access to the digital content of these books at home" (Student teacher 53).

Moreover, student teachers stated the view that bias in favour of traditional teaching methods might lead to teachers' rejection of technology (17%) and subsequently hinder AR books' integration in schools. As one of them reported, "a possible barrier to the use of AR books could be some teachers' unsophisticated attitudes which make them support strongly traditional methods and reject anything new before even trying it" (Student teacher 153). The lack of instructional time, as a result of the increased curriculum that needs to be taught based on the government's educational policy (9%), also constitutes a possible barrier:

> Taking into consideration the overloaded curriculum, I do not think there will be plenty of time for me to proceed with the utilization of a new learning tool. (Student teacher 209)

6.5 Perceived Relative Advantage over "Unaugmented" Books

Besides behavioural, control and normative beliefs, the analysis of the data enabled the identification of the perceived relative advantages of AR books over standard print books. The results revealed that the majority of participants (66%) reported the strong possibility of increased enhancement in their future pupils' interest and increased reinforcement of their engagement compared to the use of traditional school textbooks.

Furthermore, the use of AR books was considered to contribute to the provision of more enjoyable and pleasant learning experiences (25%), as well as to the development of better knowledge, perception, and understanding levels (24%), compared with the use of "unaugmented" books. Student teachers also indicated the added value of AR books in terms of the immediacy of contact with the teaching object (23%), the interactivity with the book (22%), the realism of the visualization and the multimodality (21%). A smaller proportion of the participants regarded the ease of information access and the information connection (13%) as advantages over print textbooks, which might constitute important facilitators for organizing their teaching lessons (12%).

The above perceived relative advantages over simple print books are reflected by the participants' following statements:

> AR books are differentiated from traditional and often boring school books. By offering pupils more playful and more interactive ways of learning, there is a higher chance to increase their appetite for learning. (Student teacher 7)

> AR books could be more beneficial for pupils, as they offer quick access to more information, more realistic images or experiences and multiple stimuli. As a result, the learning process can become more impressive, more pleasant and more experiential. Thus, the possibility of delivering better learning outcomes is reinforced. (Student teacher 34)

> The augmentation of these books with three-dimensional images and animations could result in increased positive attitudes by pupils towards books in general and facilitate the understanding of their content. Since visualization is achievable from multiple perspectives, understanding is facilitated much more than reading conventional books with two-dimensional images. (Student teacher 131)

> The use of AR books will enable the participation of all pupils in the learning process. In contrast to traditional print books, pupils' understanding of lesson content could become more feasible, including those pupils with specific learning disabilities and special education needs. (Student teacher 105)

> AR books are much more impressive than ordinary books due to the fact that they make inanimate objects and pictures come alive. (Student teacher 22)

> The interactive nature of AR books makes them more attuned to the requirements of the current technological reality. (Student teacher 54)

7 Discussion

The aim of this study was to explore student teachers' beliefs towards the educational use of AR books. The results showed the sample's strong intention to utilize augmented books in their future teaching and their high perceived ease of use. Additionally, a number of behavioural, normative and control beliefs concerning AR books' incorporation in teaching were identified.

In particular, student teachers' behavioural beliefs included their perceptions about the advantages and disadvantages of their future use of AR books. Most of the reported perceived advantages were relevant to AR books' perceived usefulness; namely their potential to enhance pupils' learning experience and improve learning outcomes. This perceived usefulness stemmed from beliefs which referred to the possible positive impact on pupils' enjoyment, engagement with the content, attentiveness, and learning effectiveness. This finding is supported by prior studies focused on the use of AR books in primary education which have affirmed pupils' enhanced interest (Hornecker and Dünser 2009; Lin et al. 2011; Oh and Woo 2008), active participation (Rambli et al. 2013), and learning achievements (Danaei et al. 2020; Nischelwitzer et al. 2007; Yang et al. 2013). Moreover, our findings coincide in some cases with previous findings about pre-service teachers' behavioural beliefs in terms of incorporating new technologies in the classroom (Sadaf et al. 2012). Other perceived advantages pertained to technological characteristics and affordances of AR books, such as their enrichment with visualized information, their interactivity, and their ease of use. Similarly, the perceived disadvantages were related to either technological issues (e.g. cost) or contingent negative effects on teaching effectiveness. These emerged from the participants' concerns over pupils' disorientation and disruption, imminent ineffectiveness of conventional books and teaching methods, a hindrance to specific skills development, as well as time constraints. However, AR books' perceived ease of use and perceived usefulness which were found in this study are of great importance, due to the fact that they constitute direct or indirect predictors of student teachers' actual intention to use augmented books in real classroom settings, as mentioned in the previous section (Koutromanos et al. 2015; Sanchez-Prieto et al. 2017; Teo 2009; Wong et al. 2013).

The results concerning normative beliefs indicated that future pupils and young teachers were the people who are most likely to influence student teachers towards the utilization of AR books. The contribution of pupils' expectations to the utilization of technological tools has been recognized by other researchers as well (Sadaf et al. 2012). In contrast to these supportive significant others, elderly teachers were regarded as very influential against AR books' integration. This derived partially from the perception that younger teachers possess technological skills in a higher degree than elderly teachers. This perception is reinforced when taking into consideration that previous studies have focused on examining the reasons why elderly teachers resist educational changes (Goodson et al. 2006; Snyder 2017). Moreover, student teachers believed that parents and administrators play a part in determining whether AR books' use could be adopted in teaching. Their possible high degree of influence on the adoption of technologically driven instruction has also been emphasized in prior studies (Sadaf et al. 2012; Sadaf and Johnson 2017).

In terms of control beliefs, this study found that the facilitation of AR books' use depends mostly on three factors related to technology, teachers and pupils, respectively. Specifically, the results showed that access to technological tools (e.g. mobile/wearable devices, internet) might constitute the most essential factor and might exert the greatest influence. The second factor was connected with teachers and included various elements, such as their technological knowledge, targeted training, technical support or peer-support, willingness, self-confidence and skills. Issues related to these two factors have been raised in previous literature which has referred – among others – to how innovation adoption could be facilitated (Choy et al. 2009; Gray 2001; Sadaf et al. 2012; Sadaf and Johnson 2017). The third factor emphasized the importance of pupils' willingness and co-operation for AR books' successful integration. From the opposing point of view, it was found that AR books' utilization could be hindered due to factors which are mainly related to technology and teachers. In particular, the possible lack of access to technological resources and teachers' possible rejection of technology were perceived as the most substantial limiting factors. In accordance with these findings, previous researchers have recognized that technology integration may be inhibited by barriers such as teachers' attitudes and beliefs towards technology, their levels of knowledge and skills, the perceived value of technology, as well as its availability and accessibility (Delello 2014; Ertmer 1999; Ertmer et al. 2012).

The characteristics of AR books which were perceived as more advantageous for teaching than "unaugmented" books coincided, in many cases, with the perceived advantages as indicated in the behavioural beliefs' data analysis. Thus, a stronger perceived learning usefulness of AR books compared to physical textbooks was revealed in terms of enjoyment, motivation, and learning comprehension. The perceived relative advantage over print books was also linked with the perceived technological affordances of AR books (e.g. interactivity, visualization).

8 Conclusions and Implications

To summarize, this study provided insight into student teachers' beliefs concerning the incorporation of AR books in teaching. Based on the findings, an initial implication of the current study is that in order to promote ideal circumstances for utilizing AR books in education and exceed the reported impediments there should be a focus on teacher education programs. It is critically important for both student teachers and in-service teachers to gain an understanding of AR books' function and learn how to take full advantage of their pedagogical affordances so as to design effective teaching strategies and learning activities for their utilization. Towards this direction, student teachers' personal engagement in the design and the development of augmented book pages, as well as in pilot implementations aiming at identifying flaws and reflecting upon the learning procedure, could be helpful. Meanwhile, student teachers' preparation regarding the challenges that are most likely to emerge, as presented in this study, and possible fruitful ways of dealing with them would be of high value.

Another implication is highlighting the importance of reinforcing the positive influence of school administrators and parents towards AR books' integration, as well as decreasing the possible emergence of negative reactions, especially from the elderly teachers. In this sense, the provision of opportunities to obtain general knowledge about the educational affordances of technology and AR books' positive impact on learning might facilitate the receptiveness of this new technological tool and restrict a priori oppositional behaviours. A third implication of the current study is addressing educational policy issues. As our study showed, a major key component for AR books' integration is the accessibility to technological resources. Consequentially, the necessity to reconsider subject areas, such as school infrastructure investments, teaching tools and curricular contents is raised.

Future research can take account of student teachers' beliefs concerning AR books and focus on developing and implementing teacher education programs, aiming at supplying with the required knowledge and skills, so as to better incorporate these books in the classroom and maximize teaching effectiveness. Furthermore, it is noted that a limitation of the current study was its conduction with a convenient sample of student teachers. Future studies can include a representative sample of student teachers, examine in-service teachers' beliefs about AR books or explore how teachers' beliefs may influence the actual use of augmented books, so that more solid conclusions can be established.

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Community of Inquiry Model in Online Learning: Development Approach in MOOCs

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1 Introduction

The emergence of MOOCs (Massive Open Online Courses) and their widespread use both in the context of higher education and lifelong learning has radically changed the way we approach education. It is no coincidence, then, that 2012 was marked by many as the year of MOOCs (Papano 2012), and to this day, there has been a dramatic increase in the number of courses offered by many universities and private organizations around the world (Shah 2019). In Greece, MOOCs, following the trend of foreign universities, were introduced with great success. There are three main bodies that offer MOOCs in the Greek language, Coursity (https://coursity.gr/), the Hellenic Open University (https://mooc.eap.gr/ and https://learn.eap.gr/), and Mathesis (https://mathesis.cup.gr/). It is a fact that Greek participants in both MOOCs of international organizations, such as Harvard and MOOCs of Mathesis, present a large proportion of participation and successful completion in proportion to the country's population and the number of registrations (Nesterko et al. 2013; Trachanas 2018) compared to the corresponding percentages of other countries abroad, a fact that also reveals the dynamics that the MOOCs, that are offered exclusively in the Greek language, can have. The reasons for this rapid growth of MOOCs are varied either economically or socially with some researchers (Garrison 2017; Kovanović et al. 2018a) emphasizing the need of society for a more accessible education.

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Researchers point out that there has been little emphasis on pedagogical models and educational curriculum design for MOOCs, even by major university institutions, as opposed to the technologies used (Holton, 2012, as cited in Baggaley 2013), and therefore there is an urgent need to support research on MOOCs by solid theoretical models, such as that of the Community of Inquiry (CoI), which sheds light on the social dimensions of learning (Gašević et al. 2014; Kovanović et al. 2018a), taking into account and the fact that the roles ascribed traditionally to teachers and students are altered in the rapidly changing distance learning environment, and specifically within MOOCs. At the same time, Gašević et al. (2014) highlight the need to study the penetration of MOOCs in areas outside of North America, where research had focused during the first decade of their rapid spread.

2 The Three Generations of Pedagogical Theories in the Context of Distance Education

As for the generations of pedagogical theories that have played a role in distance education, of which MOOCs are a part, we could say that these are three, following the evolutionary course of the technologies used. Thus, the first generation of pedagogical theories is related to cognitive and behavioral theories, the second to social constructivism, and the third to the theory of connectivism (Anderson and Dron 2011). Cognitive and behavioral theories seem to apply to older forms of distance education, while connectivism, according to some researchers, cannot be considered an autonomous pedagogical theory (Verhagen, 2006, as cited in Kop and Hill 2008), but more a branch of constructivism (Kerr, 2007a, as cited in Kop and Hill 2008). Thus, in recent decades, the theory of social constructivism has been gaining ground in the field of distance education. According to Siemens (2004) constructivism refers to the active role that students should play in the learning process depending on individual needs, so that they construct meaning. On the other hand, according to the researcher, social constructivism focuses on the cognitive processes that play an important role in processing and reconstructing reality. These processes are necessary, so that the individual understands the environment in which he acts and integrates as a member of a community that works together and exchanges views. In fact, according to Anderson and Dron (2011), the three main factors in the learning process – teachers, students, and content – remain the same in all three generations of pedagogical theories, but what is changing is the different degree of interaction between these three factors.

3 The Community of Inquiry Theoretical Framework

The CoI theoretical framework (Garrison et al. 2000), which is part of the theory of social constructivism, is based on the theories of Dewey (1933), Peirce (1955), and Lipman (1991) on the collaborative reconstruction of knowledge and can be described as "a generic and coherent structure of a transactional educational experience whose core function is to manage and monitor the dynamic for thinking and learning collaboratively" (Garrison 2017, p. 24). The individual as a social being builds his personal learning environment, based on his interactions with the social environment (Dewey, 1959, as in Swan et al. 2009). Furthermore, inquiry processes are a key element of a learning-oriented community (Dewey, 1959, as in Swan et al. 2009). Therefore, this theory can be applied especially in higher education, as the dialogue that develops between its members and consequently the necessary reflection can lead to the development of a higher class of critical thinking (Garrison 2017; Swan et al. 2009). Thus, the CoI framework focuses primarily on the individual's interaction with other members of the community, whether they are students or teachers, the individual's interaction with the pedagogical material, and his or her active participation in the learning process. This pedagogical model has been used mainly in higher education both in educational design (Cleveland-Innes et al. 2017) and in various courses either using exclusively distance education methodology (Akyol and Garrison 2008; Richardson and Swan 2003) or in blended learning environments (Akyol et al. 2009), while its dynamics has been proven with empirical studies (Anderson et al. 2001; Richardson and Swan 2003), but also with the factor analysis (Arbaugh and Hwang 2006; Garrison et al. 2004, 2010b; Dempsey and Jang 2019), and the validation of the corresponding questionnaire in the English version initially (Arbaugh 2007; Arbaugh et al. 2008; Kozan and Richardson 2014), and in other languages as well (Horzum and Uyanık 2015; Ma et al. 2017; Moreira et al. 2013; Öztürk 2012; Velázquez et al. 2019; Yu and Richardson 2015). The questionnaire has only recently been validated in MOOC environments (Kovanović et al. 2018a), demonstrating the dynamics of this theoretical framework in a variety of areas of distance education. In fact, Garrison (2017), one of the founders of the CoI framework, does not hesitate to state that it meets all the requirements to become a pedagogical theory.

The CoI framework is based on the three presences, the teaching presence (TP), the social presence (SP), and the cognitive presence (CP). These three components of the model are interconnected and interdependent and therefore should always be studied in relation to each other. In fact, as the interaction between the presences is what influences the direction that the CoI will take (Garrison et al. 2010a, 2010b), each time the grade of the three presences will be different, but the ultimate goal remains to achieve learning.

Teaching presence concerns "the design, facilitation, and direction of cognitive and social processes for the purpose of realizing personally meaningful and educationally worthwhile learning outcomes" (Anderson et al. 2001, p. 5) and is considered by the model's rapporteurs as the cohesive factor of the other two dimensions despite the absence of non-linguistic features of the discussion (Garrison et al. 2000). The three sub-groups of TP, alluded to the previous definition, are design, direct instruction, and facilitation (Anderson et al. 2001), instructional activities that are necessary before and during the course. Although TP is primarily the responsibility of the teacher, specific responsibilities can be shared equally among the participants (Garrison et al. 2000).

Social presence is the dimension that has been studied more than the other two and for which the definitions vary. Garrison (2009b, as in Garrison 2017, p. 25) defines SP as "the ability of participants to identify with a group, communicate openly in a trusting environment, and develop personal and affective relationships progressively by way of projecting their individual personalities." Subgroups of SP are affective expression, open communication, and group cohesion (Garrison 2017) with the above indicators following an evolutionary course from the first to the third (Garrison and Arbaugh 2007).

Cognitive presence is defined as "the extent to which the participants in any particular configuration of a community of inquiry are able to construct meaning through sustained communication" (Garrison et al. 2000, p.3). CP is one of the three dimensions that has been studied less empirically to date (Garrison and Arbaugh 2007). Consequently, it is the dimension in which future research should focus specifically on non-formal education environments, where in many cases participation in activities, such as forum discussions or self-assessment tests, is not mandatory. This is also evident from the shift of researchers dealing with the CoI framework to the study of metacognitive skills necessary to achieve learning (Akyol and Garrison 2011; Garrison 2017; Garrison and Akyol 2015a, b). The four phases of the "construction" of CP, based on the Practical Inquiry Model (Dewey 1933), are: triggering event, exploration, integration, and resolution (Garrison 2017; Garrison et al. 2000).

Of course, the special features of MOOCs, such as the large number of participants, the limited teaching presence, the optional nature of participation in MOOCs, and the corresponding discussions of forums resulting in different patterns of participation in them, lead us to the conclusion that MOOCs differ from traditional online courses (Clow 2013; Hew and Cheung 2014), which raises doubts among researchers as to whether theories such as social constructivism can be applied to MOOC environments and especially xMOOCs (Poquet et al. 2018), which focus on traditional knowledge reproduction through linear video monitoring and participation in assessment tests. In contrast, cMOOCs seem to have characteristics, such as the high degree of self-efficacy and commitment of participants and the achievement of learning through "connected" users (Siemens, 2012, as cited in Baggaley 2013), which refer to the theory of social constructivism. However, it is a fact that xMOOCs will gradually acquire the characteristics of cMOOCs (Downes 2012).

4 Online Discussions in the Context of MOOCs

The CoI framework is a socio-constructivist framework that argues that the main tool for building knowledge is dialogue (Garrison et al. 2000), thus focusing on the Socratic method of discovering the truth. In fact, Agarwal (2014), the CEO of Edx, one of the largest providers of MOOCs, refers to "the ultimate Socratization of education." At the same time, the percentage of participants who do not complete the MOOCs is high, reaching up to 90% of the initially enrolled students (Hew and Cheung 2014), with researchers using the term "the funnel of participation" to describe the phenomenon (Clow 2013). Downes (2014) refers to successful completion rates of MOOCs ranging between 0.67% and 19.2% while, according to Garrison (2017), perhaps one of the reasons for the high rate of leaks is the difficulty of participants in engaging in constructive dialogue. It is therefore important to consider how MOOC users participate in discussions, given the differences in how they participate in MOOCs in relation to traditional online courses. The large number of participants, which can reach up to 50,000 (Clow 2013), the difficulty of "navigating" into the "threads" of the discussion, the limited duration of the courses, the non-compulsory nature of the participation, the limited participation of the teacher or facilitators of discussions that may be members of the community of participants, can make it difficult to participate in forum discussions, especially given that in MOOC environments participants fail to take advantage of the necessary metacognitive skills, which may be due to the absence of any external motivation (Kovanović et al. 2018b) or the incomplete presence of the teacher, which is mainly due to the pedagogical planning of the specific courses.

It is, therefore, a fact that participation in MOOCs' online discussions is relatively limited and ranges between 10% and 20% of registered participants (Allon 2012; Breslow et al. 2013; Koutropoulos et al. 2012, as cited in Hew and Cheung 2014; Onah et al. 2014). At the same time, the research focuses on the different types of participants and in particular on those who "passively" follow the discussions of the forums without participating in them, which constitute the largest percentage of participants (Bergner et al. 2015, as cited in Poquet et al. 2018; Breslow et al. 2013; Koutropoulos et al. 2012, as cited in Hew and Cheung 2014). The term used for this category of users is lurker, who, according to English Oxford Living Dictionaries, "is a person who lurks, in particular a user of an Internet message board or chat room who does not participate" (Lurker n.d.), while, according to Cambridge dictionaries online is "someone who reads the messages in a chat room without taking part" (Lurker n.d.).

It is therefore questionable whether reduced participation in MOOC forums and different ways of participating in them can lead to the acquisition of knowledge, especially given that the theory of social constructivism focuses on the interactive negotiation of ideas within spaces of exchange of views, such as online discussions. However, researchers do not rule out increased learning outcomes even for people who participate "passively" and without contributing to the discussion of MOOCs (Soffer and Cohen 2019; Wise et al. 2014, as cited in Kovanović et al. 2018b). At the same time, what seems to matter is not so much the amount of messages as the quality of them (Garrison and Cleveland-Innes 2005) and it is up to the teacher to achieve a smooth transition from social presence to cognitive presence, which is of course the final goal of a course while the high degree of social presence is associated with a higher degree of participation in online discussions, according to research by Swan and Shih (2005). At the same time, according to the research of Wong et al. (2015), the contribution of active users in the online discussions of MOOCs has a significantly positive role in them according to the perception of the other participants, while in the research of Chiu and Hew (2018) the results indicate that peer learning and performance were primarily predicted by viewing, and to a lesser extent by commenting in the forums.

5 Aim and Research Questions

The aim of this research was to study the extent to which the CoI framework can be applied to MOOC environments and whether, therefore, socio-constructivist learning theories can be valid for MOOC environments and in particular xMOOCs. It focuses on the MOOCs offered in the Greek language and especially one of the existing platforms. The research questions that have arisen are the following:

RQ1. What is the level of development of the Community of Inquiry? And therefore:

(a) What is the correlation between teaching presence and cognitive presence?
(b) What is the correlation between social presence and cognitive presence?
(c) What is the correlation between teaching presence and social presence?

RQ2. Is there a correlation between demographics (gender, age, level of study, previous experience in MOOCs) and the level of development of the CoI?

RQ3. Is there a correlation between the degree of participation in forum discussions and the degree of development of the CoI?

6 Sample and Research Procedure

The participants of this research have participated in MOOCs on the Greek platform of Mathesis (https://mathesis.cup.gr/) (n = 79). Mathesis is offering MOOCs in the Greek language since 2015. Most Mathesis courses last up to 6 weeks, while, according to Trachanas (2018), their subject can be divided into three categories: general education courses, training-specialization courses in modern subjects, and introductory university courses for students, teachers, and citizens with special interests. The course instructors are leading university teachers from domestic and foreign universities, while teaching support is also provided by teaching assistants or course participants, who take on a more active role (Trachanas 2018). Until 2018, the platform had about 45,000 registered users and 31,000 certificates of successful monitoring have been issued (Trachanas 2018). The instrument of the research was the questionnaire of the CoI, which was translated into Greek by the method of reverse translation (Brislin 1986). In the translation, instead of the word "teachers," the phrase "the teacher and teaching assistants" was used, according to the change made by Kovanović et al. (2018a). The CoI questionnaire (Arbaugh et al. 2008) consists of 34 questions, which are answered on a 5-point Likert scale (1: strongly disagree, 5: strongly agree), of which 13 concern the dimension of TP (e.g., "The instructor was helpful in identifying areas of agreement and disagreement on course topics that helped me to learn"), 9 the dimension of SP (e.g., "Getting to know other course participants gave me a sense of belonging in the course"), and 12 the dimension of CP (e.g., "Learning activities helped me construct explanations/solution"). Questions related to the demographic characteristics of the participants were utilized, as well as the degree of participation in the discussions of the respective forums. The statistical tests performed in the present study are non-parametric, as the normality does not apply to all variables. The statistical analysis of the answers was done with the SPSS 25 program.

After a personal e-mail contact with Mr. Garrison, he gave the permission for the questionnaire to be used in a survey in the field of MOOCs. The questionnaire was made available the period between the 28th of March and sixth of May 2019 to three Facebook groups that support non-formally the lessons of the Mathesis platform. The specific mode of questionnaire distribution was chosen due to the large number of group members (more than 1000 members each). Seventy-nine questionnaires were completed and the degree of response to the completion of the questionnaire is equivalent to the degree of response to corresponding surveys abroad (Kovanović et al. 2018a, b).

7 Results

7.1 Demographic Characteristics and the Degree of Registration and Completion of MOOCs

The demographic characteristics and the degree of registration and completion of MOOCs can be observed as follows. In terms of gender, the largest percentage of participants are women (59.5%), while in terms of age group most participants belong to the third age group with a range from 55 to 80 years (53.2%). In terms of the highest level of education, most participants (81%) report a high level of education (tertiary education and above). As for the previous experience in MOOCs, the largest percentage (78.5%) has extensive experience in MOOCs, having attended more than six MOOCs, while in terms of the degree of completion of MOOCs the largest percentage (68.4%) has completed more than six courses. There is a very

Table 1 Mean and standard deviation value of TP, SP, CP, and CoI

N = 79	Mean	SD
TP	4.4372	0.51418
SP	3.6596	0.89463
CP	4.1329	0.60278
CoI	4.1240	0.54583

strong and positive relationship between the degree of participation in MOOCs and the degree of their completion (r = 0.826) at a level of importance of 1%, which means that those who enroll in MOOCs largely complete them. Of the Mathesis MOOCs, the majority of participants wanted to refer to humanities courses (82.3%), while a smaller percentage wanted to refer to science courses (17.7%). Also, the largest percentage of participants has successfully completed the MOOC (86.1%).

7.2 Reliability Degree

The degree of reliability of the CoI questionnaire (Chronbach's Alpha) taking into account the three dimensions of the theoretical model is quite high (α = 0.948) and corresponds to the degree of reliability of the questionnaire in corresponding surveys (Kovanović et al. 2018a; Yu and Richardson 2015), while the degree of reliability of the individual dimensions is less than the general degree of reliability and ranges from 0.888 for the dimension of CP to 0.918 for the dimension of TP to 0.937 for the dimension of SP.

7.3 RQ1. What Is the Level of Development of the Community of Inquiry?

Regarding the degree of development of the Community of Inquiry, we could observe the following. The mean value of the SP dimension is low (Table 1), a fact that is also found in similar research in the field of MOOCs (Kovanović et al. 2018a). The mean values of CP, TP, as well as the mean value of the CoI are generally satisfactory (Table 1). Of the three sub-groups of TP (design, facilitation, and direct instruction) (Table 2), the sub-group of direct instruction had the lowest mean. Of the three subgroups of SP (affective expression, open communication, and group cohesion) (Table 3), the sub-group of the group cohesion had the lowest mean value, while of the four phases of CP (triggering event, exploration, integration, and resolution) (Table 4) the phase of exploration had the lowest mean value.

A non-parametric Spearman's rho test was performed to test the correlation between the three presences, as the sample did not follow the normal distribution. According to Katsis et al. (2010), values from 0.41 to 0.60 suggest a moderate

Table 2 Mean and standard deviation value of TP sub-groups

N = 79	Mean	SD
TP1.1 (design)	4.7500	0.38605
TP1.2 (facilitation)	4.3460	0.61020
TP1.3 (direct instruction)	4.2025	0.75564

Table 3 Mean and standard deviation value of SP sub-groups

N = 79	Mean	SD
SP1.1 (affective expression)	3.7342	0.95090
SP1.2 (open communication)	3.6878	1.00191
TP1.3 (group cohesion)	3.5570	0.97215

Table 4 Mean and standard deviation value of CP sub-groups

N = 79	Mean	SD
CP1.1 (triggering event)	4.4008	0.60005
CP1.2 (exploration)	4.0042	0.79078
CP1.3 (integration)	4.0633	0.82185
CP1.4 (resolution)	4.0633	0.79003

Table 5 Correlations between the three presences (Spearman's r test)

	TP	SP	CP
TP		0.509*	0.673*
SP	0.509*		0.599*
CP	0.673*	0.599*	

*$p < 0.01$

correlation, while values from 0.61 to 0.80 suggest a strong correlation. Based on the correlation test between the three dimensions of the CoI, we can argue that its degree is satisfactory, as there is a moderate and positive correlation between TP and SP, strong and positive correlation between TP and CP, moderate and positive correlation between SP and CP (Table 5).

These results are likely to give us important information about the formation of the CoI in the context of MOOCs and the directions that the design of the respective courses should take. As Garrison (2017) points out, the three dimensions of the CoI are interdependent and as such we must address them based on rigorous research and for this reason, we can argue that the degree of formation of the CoI is satisfactory if we consider the mean values of the three presences and the degree of their correlation. Although we note that TP plays an important role for learners especially in countries with higher student-teacher ratios, such as India (Guo and Reinecke 2014), or countries with a long tradition in frontal teaching, such as China (Zhang et al. 2018) and Greece, respectively, we observe that it is understood by the participants in this study that the direct instruction is not strong, as evidenced by the low mean value compared to the other two sub-groups, as well as the greater standard deviation score. Regarding SP, we could notice the following. As Matthews et al. (2013, as cited in Kovanović et al. 2018a) suggest, a mean value below 3.75 represents aspects of students' learning experience that need further inspection and improvement. But, it is a fact that low mean scores are also found in similar research in the field of MOOCs (Kovanović et al. 2018a), as some aspects of SP are difficult to develop within the narrow time frames of MOOCs and given the large number of participants. The high standard deviation value in the variables of SP (Tables 1 and 3) is an indication of how differently participants perceive it. Respectively, the low mean value of group cohesion (Table 3) leads to the observation that in the future the design of MOOCs should focus on the use of tools, such as social networks, which will probably enhance the sense of belonging to the community, while emphasizing to the important role of the teacher. Finally, the low mean value of the exploration phase (Table 4) should not come as a surprise, as we are referring to humanities' mainly courses belonging to the category of xMOOCs.

The results related to the degree of correlation of the three presences agree with the results of previous research, conducted in the field of MOOCs and in the field of distance education. Specifically, in the Kozan and Richardson (2014) study, CP had a high and positive correlation with TP ($r = 0.694$) and SP ($r = 0.596$), while the correlation between TP and SP was positive and moderate ($r = 0.450$). Respectively, the research of Garrison et al. (2010b) showed a moderate and positive relationship between TP and CP ($r = 0.51$), a moderate and positive relationship between TP and SP ($r = 0.52$), and a moderate and positive relationship between SP and CP ($r = 0.40$). Finally, the research of Kovanović et al. (2018a) in the field of MOOCs showed a high and positive correlation between TP and CP ($r = 0.61$), small and positive correlation between TP and SP ($r = 0.33$), and small and positive correlation between SP and CP ($r = 0.34$). The fact that in our research the correlation between TP and CP was high and positive and between TP and SP moderate to high and positive can, most likely, be explained by the important role that teachers and teaching assistants play in facilitating of learning. Typically, the high-level academic staff involved in Mathesis courses is a pole of attraction for many participants, while, as Trachanas (2018) points out, participants volunteer as teaching assistants, forming around the MOOC forum a community where one learns from the other.

7.4 RQ2. Is There a Correlation Between Demographics (Gender, Age, Level of Study, Previous Experience in MOOC) and the Level of Development of the Community of Inquiry?

The Spearman's rho test (Table 6) showed that there is a zero correlation between gender and the degree of development of the CoI. There is a small and positive correlation between the age and the degree of development of the CoI. The study showed that there is a zero correlation between the level of study and the degree of development of the CoI and between the previous experience in MOOCs and the degree of development of the CoI.

The non-parametric Kruskal-Wallis test showed that there were no statistically significant differences in TP and CP per age group. However, there are statistically

Table 6 Correlations between CoI and gender, age, level of study, and previous experience (Spearman's rho test)

	CoI
Gender	0.051*
Age	0.247**
Level of study	−0,114*
Previous experience	0.052*

*p > 0.05
**p < 0.05

significant differences ($p < 0.05$) in SP per age group with the age group of 55–80 having a higher mean value of SP regarding to the age group of 18–38, and with the age group of 39–54 having a higher mean value of SP regarding to the age group of 18–38. Accordingly, there are statistically significant differences in the degree of development of CoI per age group ($p < 0.05$) with the age group of 55–80 having a higher mean value of the degree of development of CoI regarding to the age group of 18–38.

These results suggest that the participants who belong to the 55–80 age group are more open to develop their social presence and to participate in the courses in a variety of ways, and this should direct the methodological approaches the teachers and instructional designers should take in order to enhance the participation of the older age group but also to encourage participants of other age groups to more actively participate in MOOCs. Finally, we should notice that these results are not irrelevant to the characteristics of MOOCs offered by Mathesis and especially the courses' thematic, as most of the courses are on topics of general interest (e.g., History and Philosophy), which may engage participants of a certain age.

7.5 *RQ3. Is There a Correlation Between the Degree of Participation in the Forum Discussions and the Degree of Development of the Community of Inquiry?*

The participation rate in the forums of the MOOCs was small, as the largest percentage of participants (55.7%) rarely participated in the discussions. The control over whether there are statistically significant differences in the degree of participation in the forums depending on the chosen course (Humanities or Science Studies) did not show statistically significant differences ($p > 0.05$), suggesting that there is a common pattern on the way students participate in the discussions and the ways they use these forums, albeit Trachanas (2018) suggests that the students in science studies' MOOCs participate in forums more actively. In addition, the correlation between the degree of participation in the forums and the degree of development of the CoI and its individual dimensions, according to Spearman's rho test (Table 7), in order to check whether the participation in the forums is related to the degree of development of the CoI, showed that between the degree of

Table 7 Correlation between CoI and the degree of participation in MOOCs forums (Spearman's rho test)

	CoI	TP	SP	CP
Participation in forums	0.411**	0.210*	0.470**	0.341**

*$p > 0.05$
**$p < 0.01$

participation in the forums of the MOOCs and the degree of development of the CoI there is a moderate correlation, zero correlation between the degree of participation in the forums of MOOCs and TP, moderate and positive correlation between the degree of participation in the forums of the MOOCs and SP, a small and positive correlation between the degree of participation in the forums of the MOOCs and CP.

From the non-parametric Kruskal-Wallis test, it was found that there are statistically significant differences ($p < 0.05$) between the mean values of SP, CP, and the degree of development of the CoI depending on the different levels of participation in the forum. More specifically, in terms of SP, the students who participated quite often had a higher mean value of SP regarding the students who did not participated in the discussions and regarding the students who participated rarely. In terms of CP, the students who participated often had a higher mean value of CP as opposed to the students who did not participate in the discussions and the students who participated rarely. Between the different levels of participation in the forum discussions and the degree of development of CoI, the results indicate that the students who participated often in the forums' discussions had a higher mean value of CoI as opposed to the students who did not participate and the students who participated rarely.

The results lead to the conclusion that, although learners are not so actively involved in the discussions, it does appear that participation is associated with SP, which is to be expected (Poquet et al. 2018). Nevertheless, the results indicate that participating actively in the discussions could lead to the enhancement of CP and to the development of a community of inquiry. Of course, an important role is to be played by the teacher or his/her assistants, who will coordinate the discussions of the forums after careful planning of the courses that will be based on the social-constructivist learning theories, and regular participants, as Poquet and Dawson (2015) suggest. In addition, among the factors that act as a deterrent to the enhancing of SP in the context of MOOCs is, for example, the short duration of courses and the large number of participants (Poquet et al. 2018) and so the expansion of the duration of courses and the use of small group forums may assist to the enhancing of SP in MOOCs. Therefore, the discussion area should stop being just a question-solving space, but it should be used functionally, so that it will be a place where learning will be conquered in a constructivist way.

8 Limitations and Extensions of the Research

A major limitation of this research is that the sample was quite small and concerned only one of the platforms that offer MOOCs in Greece. Of course, the practices followed by the Mathesis platform (courses offered, method of teaching, and use of teaching assistants, the audience to which they are addressed) are corresponding to major universities abroad, which are oriented mainly to xMOOCs.

The proposals for its expansion could include the correlation of the sub-groups of the three presences with each other but also with the special characteristics of the participants, as it would be useful to check this in the context of MOOCs, where their particular characteristics are different in relation to traditional distance education courses. Finally, it would be useful to present the Greek translation of the CoI questionnaire to Greek participants in MOOCs of providers abroad, given the large percentage of successful participation by Greeks (Nesterko et al. 2013) and to compare research results with the corresponding results from the application of the Greek translation to participants in MOOCs of Greek providers. It is also important to explore the dynamics of Greek Facebook groups that are supportive of MOOCs, as they appear to be informal, but they help significantly in the learning process and their members are what Siemens refers to as “connected” users (Siemens 2004). Certainly, the use of learning analytics and social network analysis can be supportive in future research. At the same time, as Reich and Ruipérez-Valiente (2019) note, research on MOOCs needs to focus on experimental teaching rather than post hoc research. In fact, it is time for Greek providers of MOOCs to experiment with new teaching methods based on solid pedagogical theories, such as that of social constructivism, as the large number of Greek participants in MOOCs suggests that the ground is suitable. This, of course, requires collaboration between universities, MOOC providers, and those involved in the production, distribution, and research on MOOCs in general (Reich and Ruipérez-Valiente 2019).

9 Conclusions

The aim of the present study was to fill the research gap observed in Greece in the field of MOOCs and to lay the foundations for the utilization of a theoretical framework in the context of MOOCs. The CoI framework and the theory of social constructivism on which it is based are emerging as valuable tools in research on MOOCs, as the above results indicate that the CoI framework may be applied in xMOOC environments. Further research in this area may be able to eliminate any reservations about the feasibility of applying the theory of social constructivism in the context of MOOCs and provide us with directions on the future of MOOCs, as in the near future we will be inclined to live in a more connected environment. The CoI framework seems to meet these specifications and may lead to research on MOOCs and distance learning in general, as Garrison (2017) notes that it has all specifications to develop from a theoretical model to a pedagogical theory in distance education. The present study, therefore, demonstrates that a CoI can also be formed in the context of MOOCs with their particular characteristics. At the same time, the present study points out the significant correlations between the components of the model, correlations that are also found in similar research (Kozan and Richardson 2014). Although Kozan and Richardson's research (2014) involved online courses in a postgraduate program, the fact that some participants may have taken more than one course leads to the assumption that the sample had a cohort characteristic, which is similar to the participants' characteristics present research. The high and positive correlation between teaching presence and cognitive presence points out the important role that the teacher and his/her assistants can play in the context of MOOCs, as well as the connection between cognitive presence and specific activities of MOOCs, such as the discussions of the respective forums, even if the degree of participation in them is small. Although social presence is considered necessary for the formation of a Community of Inquiry, it is the teacher who will strengthen it with the appropriate teaching actions in order to achieve a high cognitive presence. In this regard, the metacognitive skills questionnaire (Garrison and Akyol 2015a, b) can prove to be a valuable tool in research on MOOCs. Therefore, researchers should focus on those teaching methods that will enhance the ability of participants to self-regulate learning, a skill that is necessary for participation in learning environments, such as those of MOOCs, where the participants are required to organize learning on their own, to process the material offered independently, while participation in discussions works in different terms than other online courses. All this leads us to the conclusion that, as Garrison et al. (2000) note, learning is not a one-sided process of transmitting knowledge from the teacher to the students, but a two-way interaction between teachers, students, and content and as such we must deal with it, especially if we take into account the new possibilities and perspectives in the field of education. When, therefore, we design and teach courses using the technology, we must not forget that the technology used is the tool, but the human factor is the one that will give learning the breath and the direction it needs.

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Computational Thinking Assessment: Literature Review

Emmanouil Poulakis and Panagiotis Politis

1 Introduction

Though the underlying ideas of Computational Thinking (CT) have a long history, the concept has attracted recent attention since Wing's (2006) conceptualization, followed by attempts to further define the term (Grover and Pea 2013), alternative proposals including *concepts*, *practices,* and *perspectives* (Brennan and Resnick 2012), and attempts to summarize commonly used concepts describing CT (Barr and Stephenson 2011; Bocconi et al. 2016; Selby and Woollard 2013). During this same period, new CT teaching resources have been created. These include CS Unplugged (University of Canterbury n.d.), Computing At School (CAS) (n.d.), and Teaching London Computing (n.d.), all of which use six basic concepts of CT: algorithmic thinking, abstraction, decomposition, generalization and patterns, evaluation and logic, based on the concepts proposed by Selby & Woollard, with the addition of logic (Bell and Lodi 2019; Computing At School 2015). Other CT resources include CT competition Bebras, which also follows the concepts of Selby & Woollard (Dagienė and Sentance 2016), CAS, which refers to techniques and approaches, and Computational Thinking with Scratch (n.d.), which refers to Brennan & Resnick's approach as well as Lye and Koh (2014) for the development of CT through programming.

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2 Computational Thinking Assessment

Many countries reform their school curricula, introducing CT (Heintz et al. 2016). Fessakis et al. (2018) analyze CT conceptualization and scope in school curricula. The successful integration of CT in primary and secondary school curricula requires CT assessment, while valid assessment tools of children's learning outcomes shall exist in order to judge the effectiveness of any curriculum incorporating CT (Grover and Pea 2013). During the last years, CT assessment approaches have been implemented, but CT assessment research still remains limited and neither covers all CT spectrum, nor all student age groups (Bocconi et al. 2016). Cutumisu et al. (2019) report the lack of valid CT assessment tools and the deficient systematic grouping of CT assessments. Mueller et al. (2017) also report the lack of reliable CT assessment tools and stress the difficulty and limitations that this deficiency brings into the development of CT in curricula, according to international organizations like ACM and CSTA.

Lye and Koh (2014) state that CT includes the use of Computer Science (CS) concepts, and thus students are exposed to CT during programming. In this manner, existing programming and algorithmic thinking assessment methods have been initially used for CT assessment. However, programming aptitude tests appeared inefficient in the past (Ambrósio et al. 2014), while lack of CT assessment items seems to exist in secondary education, thus leading teachers to develop their own assessments, which do not always accurately assess student learning (Yadav et al. 2015). The development of CT assessment tools is a demanding and not an empirical process, and tools which have been designed for different processes cannot be adopted without the necessary readjustment and evaluation.

3 The Research

3.1 Target and Goals

This study conducts a literature review aiming at analyzing CT assessment approaches and is based on principles of qualitative content analysis (Bryman 2008). The six-step procedure of Altheide (2004, cited in Bryman 2008) is followed for the content analysis process and the generation of categories, so that the categories gradually emerge. The main target is the survey of CT assessment evolution to investigate if it is in a premature or mature stage, if it can cover all age groups, and finally the listing of current research trends, as they have been formed during the last decade.

In particular, the goals of this literature review consist of researching CT assessment approaches in terms of:

- Required parameters of application (i.e., age, specific programming environment, etc.)
- Methodology of assessment implementation (i.e., automated, etc.).

Table 1 Research sample per database search

Database	Results	Exclusion from sample	Inclusion in sample
ACM digital library	179	144	35
IEEE Xplore digital library	53	42	11
Elsevier science direct	175	161	14
Springer link	540	526	14
Total	**947**	**873**	**74**

3.2 Method

In order to search and collect relevant articles, a query has been conducted in four databases, which were technically available: (a) ACM Digital Library, (b) Elsevier Science Direct, (c) IEEE Xplore Digital Library, and (d) Springer Link. The query used the keywords "computational thinking" and "assessment" or "assessing" under the logical scheme "COMPUTATIONAL THINKING" AND ("ASSESSMENT" OR "ASSESSING"). The articles have been initially reviewed by their titles, keywords, and abstracts. Inclusion criteria consist of specific reference to CT and its assessment, usually by the use of the words CT and "assess," "measure," "evaluate," as well as their derivatives, or the concepts presented in the abstract. The initial large number of results was expected due to the wide time frame (a decade). Despite the initial large number of results of Springer Link, many of them were not relevant to the query (e.g., results relevant to "digital literacy" or "ICT literacy") and were ultimately excluded.

The initial search included the decade 2010–2019. Space limitations of this study resulted in choosing only a few documents concerning each tool/method. The final number of included documents sums up to seventy four (74), as presented in Table 1. Each separate document is the unit of analysis.

3.3 Data Analysis

Specific predefined parameters, as well as parameters that emerged during the research according to its target, were taken into consideration for the documents' content analysis. The six-step procedure of Altheide (2004, cited in Bryman 2008) was followed. Bearing in mind the research questions, we were already familiar with the content within which the documents were generated. Next step was to become familiar with a small number of documents of the sample, proceeding to the generation of some categories that could guide the collection of data, and drafting a schedule for collecting the data in terms of the generated categories. Finally, we tested the schedule by using it for collecting data from a number of documents, revised it, and selected further cases to sharpen it up.

The documents were initially reviewed based on the age of students that assessment schemas refer to. It was intensely observed that researchers did not clearly mention the proposed age groups, and usually applied their approach to a small sample of their choice, leading to a convenient sample. Only a few of the tools have been thoroughly validated. In the Results section, the research approaches are presented briefly, while reference is made to age groups and assessment concepts.

A review of documents on the basis of their approaches then followed. A large amount of approaches designed for specific programming environments emerged, also some approaches using climates or psychometric tools, and some approaches following a blended methodology using multiple forms/methods of assessment, which do not rely on a unique tool. The categories that emerged are analytically presented in the Results section.

Finally, another review parameter is the existence of the connection of each proposed method with the teaching process, namely if the teaching activities are taken into consideration or the proposed method constitutes an autonomous CT assessment tool. Very few tools can probably autonomously assess CT, mainly in the category of psychometric tools/criteria; furthermore, the adequacy of independent from teaching processes tools to assess CT was examined.

After distinguishing all previously mentioned parameters (age, approach, connection with teaching) and the consequent category creation, a brief presentation of the tools/assessment methods was decided and organized in the categories that emerged.

4 Results

Román-González et al. (2019) report seven categories of CT assessment approaches: (a) diagnostic tools, (b) summative tools, (c) formative-iterative tools, which provide feedback, (d) data-mining tools, (e) skill transfer tools, (f) perceptions-attitudes scales, and (g) vocabulary assessment. In this study, the categories of CT assessment that emerged from content analysis are:

(a) *Using specific programming environments*, which is connected with the implementation environment of each artifact (program or educational game), and in some cases is fully automated. Approaches are differentiated in the case of *game construction*, which emerges as a subcategory, as researchers introduce new areas and assessment concepts, that are not used in the remainder of CT spectrum, such as game mechanics.
(b) *Using CT assessment criteria and/or psychometric tools*, in which perceptions-attitudes scales are included and mentioned by Román-González et al. (2019), and the attempts of CT connection with metacognitive factors or personality characteristics, in an effort to study CT from a psychometric approach.
(c) *Using multiple forms of assessment*, which consist of project portfolios, participant observation, artifact-based student interviews, etc., and differentiate

according to the proposed research frame. A differentiation of assessment concepts and practices is also observed in STEM CT approaches, for example, when simulations appear. Due to this, it could be considered a separate subcategory, but in this study, it is included in multiple forms of assessment.

The categories are not always independent, i.e., in the categorization of Román-González et al. a CT diagnostic tool can be used as a CT summative tool in posttest conditions, while this study's category multiple forms of assessment could also refer to specific programming environments.

4.1 CT Assessment Using Specific Programming Environments

The frequent use of programming in CT development approaches situates programming as a basic field for assessing CT concepts. Several environments are used, many of which aim at game construction, while Scratch is dominant.

CT is automatically assessed in AgentSheets/AgentCubes in middle schools using graphs which visualize the programming pattern implementation (generations, absorption, collision, transportation, push, pull, diffusion, hill climbing, cursor control), namely techniques that appear in game construction, while the REACT system produces real-time information of projects helping formative assessment (Basawapatna et al. 2015; Koh et al. 2010). The Fairy Performance Assessment tool in Alice uses prior assessment scenarios in AgentCubes (Webb 2010) and correction/completion of given code, assessing algorithmic thinking and effective use of abstraction and modeling in middle schools (Werner et al. 2012). Additionally, in middle schools, Game Computational Sophistication (GCS) assesses programming construction, patterns, and game mechanics in Alice (Werner et al. 2015). Another CT assessment approach in the Zoombinis game proposes the development of a human labeling system for evidence of specific CT skills (problem decomposition, pattern recognition, algorithmic thinking, abstraction), by analyzing video data, with elementary and middle school students, as well as experts (Rowe et al. 2017).

Several modern programming environments, e.g., Scratch, App Inventor, are block-based. Basu (2019) introduces an assessment rubric for both environments, while Commutative Assessment involves programming concepts (variables and comprehension, conditionals, loops, functions, and algorithms) and uses a comparison between code forms (blocks-text) in grades 9–12 (Weintrop and Wilensky 2015). In App Inventor, rubric MCT measures 14 CT properties (general CT, e.g., naming, procedural abstraction, variables, loops, conditionals, lists, and eight more Mobile CT properties) of an app (Sherman and Martin 2015) and Quizly, an online platform, uses questions on App Inventor components-structures and automated answer assessment with 14- to −16-year-olds and tertiary students (Maiorana et al. 2015).

In Scratch, the Progression of Early Computational Thinking (PECT) model uses programs and rubrics (Seiter and Foreman 2013) dealing with procedures and algorithms, problem decomposition, parallelization and synchronization, abstraction, and data representation in grades 1–6. Dr. Scratch is an automated assessment tool, in which the analysis of the learner's project portfolio is suggested, in order to provide a more accurate picture of CT skills (abstraction and problem decomposition, logical thinking, synchronization, parallelism, algorithmic notions of flow control, user interactivity, and data representation) in grades 5–10; Dr. Scratch has already undergone several validity checks (Moreno-León et al. 2016; Moreno-León et al. 2017a, b). Dr. Scratch is used in both formative and summative assessments (Troiano et al. 2019), but Hoover et al. (2016) report a difficulty in adequately assessing and comparing project complexity, indicating differences between the quantitative and qualitative analyses.

Additionally, Ninja Code Village for Scratch (NCV) is an automated assessment system of programming concepts (conditional statements, loops, common procedure, data, events, parallelism, user interface) in primary schools (Ota et al. 2016), while Chang et al. (2018) recently developed the Scratch Analysis Tool (SAT) which deals with abstraction and problem decomposition, parallelism, logical thinking, synchronization, flow control, user interactivity, and data representation. Moreover, Functional Understanding Navigator! (FUN!) automatically analyzes Scratch programs on concepts parallelism, logical thinking, synchronization, iterative and recursive thinking, and pattern generalization, producing as output worksheet files, in grades 5–8 (Brasiel et al. 2017). Finally, Srinivas et al. (2018) propose an assessment based on analysis of transaction-level Scratch log data, providing at the same time a data visualization tool.

Arslanyilmaz and Corpier (2019) intend to use eye-tracking technology as an objective assessment tool for the comprehension of CT concepts, mainly programming ones, in block-based environments. However, Papavlasopoulou et al. (2019) have used eye-tracking in combination with qualitative data, and report that eye-tracking did not confirm the differences in the strategies, implemented practices, and perceptions during coding, that qualitative results brought out.

4.2 CT Assessment Criteria and Psychometric Tools

Several criteria and psychometric tools, which occasionally include blended approaches, attempt to autonomously assess CT.

Ambrósio et al. (2014) propose a tool entitled Computational Thinking Test, which is used to relate CT to the Cattell-Horn-Carroll (CHC) framework of intelligence, and particularly to spatial reasoning, induction, and working memory. Computational Thinking Test (CTt), different than the aforementioned, uses multiple-choice questions mainly covering programming concepts; its creators suggest to complement its use with other CT assessment tools, like Dr. Scratch (Román-González et al. 2017). Román-González et al. cite previous results of Ambrósio et al. and use CTt with elements of CHC, reporting correlations of CT with inductive reasoning, spatial, and verbal abilities and the problem-solving ability, thus confirming the association of CT with core CHC elements and the conceptualization of CT as a problem-solving ability. CTt has undergone several validity checks with 10- to 15-year-old students (Román-González et al. 2016, 2018a, b; Tsarava et al. 2019). Additionally, Pérez-Marín et al. (2018) created the PCNT, which also assesses mainly programming concepts, filling in the age gap of CTt as PCNT aims at children younger than 10, and uses both tests for pre and posttesting.

The psychometric tool entitled Test for Measuring Basic Programming Abilities (Mühling et al. 2015) is designed as a pre and posttest assessment of basic programming concepts for 7- to 10-year-old students based on Bebras tasks. Bebras contest aims at promoting Informatics and CT. Its tasks relate to specific Informatics or CT concepts, comply with specific qualitative criteria (age group, required time, etc.), and have already been used in assessments (Dagiene and Stupuriene 2016), sometimes in combination with other supportive tools (Pérez and Valladares 2018). However, Araujo et al. (2017) report that measures cannot be derived from Bebras in its current form. Moreover, Djambong et al. (2018) do not report important findings using Bebras tasks combined with theirs, in an assessment of 11- to 14-year-old students. Additionally, Araujo et al. (2019) and Palts and Pedaste (2017) conduct a factor analysis using Bebras tasks and both studies do not statistically confirm all Bebras' CT concepts, but report two main, more general, factors: *evaluation ability* and *algorithmic thinking and logical reasoning* for the first study, and *algorithmic thinking* and *finding patterns* for the second. Wiebe et al. (2019) combine CTt and Bebras tasks concluding to a pretest assessment for 11- to 13-year-old students, and report high correlation of CTt with Dr. Scratch and of CTt with a selected set of Bebras tasks. Finally, in tertiary education, Rojas López and García-Peñalvo (2016) combine Bebras tasks and questions from Computer Olympiad "Talent Search" for new students' pretest assessment of CT skills, while Gouws et al. (2013) also create a first-year students' pre and posttest assessment, based on "Talent Search" questions.

Furthermore, the scale Computational Thinking Scales (CTS) attempts to determine levels of specific CT skills (creativity, algorithmic thinking, critical thinking, problem-solving, cooperativity), and has undergone validity and reliability checks with university students (Korkmaz et al. 2017) and has also been adapted for secondary education (Durak and Saritepeci 2017).

Yagci (2019) developed a scale for measuring CT skills (problem-solving, cooperative learning and critical thinking, creative thinking, and algorithmic thinking) of high school students, which has undergone validity and reliability checks. Leifheit et al. (2019) construct and use a questionnaire to measure self-concept, motivational beliefs, and attitude toward programming, with elementary school students, in combination with CTt to measure CT skills, but report no significant associations of questionnaire and CTt results.

Finally, Basso et al. (2018) propose the inclusion of nontechnical skills (relational skills and cognitive life-skills) in addition to domain-specific ones, for a comprehensive CT assessment framework.

4.3 Multiple Methods of Assessment

Brennan and Resnick (2012) propose a qualitative CT assessment approach consisting of project portfolio analysis, artifact-based interviews, and design scenarios in Scratch. The importance of students' project portfolio is emphasized and research has been conducted with 8- to 17-year-old students. The assessment framework is used widely, e.g., in Arduino environment (Curasma et al. 2019), and is extended with supplement skills for K-9 education (Zhang and Nouri 2019).

Foundations for Advancing Computational Thinking (FACT) curriculum proposes structured formative and summative assessments, Scratch assignments, as well as artifact-based interviews for middle school students (Grover 2017; Grover et al. 2014). Rubrics, and not automated assessment are used; summative assessment includes posttests, final projects, and written reflections, mainly involving algorithmic thinking and programming. "*Systems of assessments*" contribute to a comprehensive picture of student learning (Grover et al. 2015).

Atmatzidou and Demetriadis (2016) approach CT assessment similarly, within educational robotics (Lego Mindstorms) with 15- to 18-year-old students. Formative and summative assessment tools, qualitative and quantitative methods, rubrics, multiple-choice questionnaires, semi-structured interviews, and teacher observation sheets are used, while a CT skills' model including the dimensions abstraction, generalization, algorithm, modularity, and decomposition is applied. In similar educational robotics (Lego Mindstorms) and advanced programming (App Inventor) approaches with 14- to 15-year-old students, Merkouris and Chorianopoulos (2019) assess CT development by collecting qualitative and quantitative data, and using pre and posttest questionnaires, semi-structured interviews, recording of on-screen activity, and analysis of students' final projects.

Chen et al. (2017) develop an instrument to assess fifth-grade students' CT, using questions (text-block) of robotics programming, as well as reasoning of everyday events in order to examine *knowledge transfer*; the instrument is used in pre and posttesting. Multiple approaches foster validity, so Lytle et al. (2019) follow a triangulated approach entitled CEO (Code traces, Exit tickets, field Observations) using student *code traces* (actions while coding), *exit ticket* (written post-activity) responses, and *field observations*, reporting positive findings with eighth-grade students. Similarly, PAWS (Personalized Assessment Worksheets for Scratch) uses interviews, written assessments, and artifact analysis in order to assess basic programming concepts with fourth-grade students (Salac 2019). PAWS uses code snippets from student artifacts as a possible bridge between the methods of assessment.

Qualitative research methods emerge as an important approach in the assessment. In addition to field observation and interviews, Lye and Koh (2014) propose the use of think-aloud protocol and on-screen programming activity capture, as well as the use of predetermined categories in content analysis. Additionally, think-aloud protocol evolves by adopting a set of teacher verbal protocols in formative assessment (Mueller et al. 2017).

Portelance and Bers (2015) attempt CT assessment for younger age groups, by analyzing artifact-based (ScratchJr) video interviews of second-grade students with each other in pairs. In addition, Marinus et al. (2018) investigate coding ability for 3- to 6-year-old students with the assessment tool Coding Development (CODE) Test 3–6, and report a relation between coding ability and cognitive compiling of syntax in natural language.

Besides age, the teaching approach emerges as a differentiation factor of CT assessment. Thus, Weintrop et al. (2014) use online assessment sets (motion charts and a climate change model in Netlogo) for CT assessment within STEM, while Swanson et al. (2019) propose a CT-STEM practices' assessment with ninth-grade students, using written student responses and scheduling future qualitative analysis of student utterances, NetLogo log files, and work. Zhang and Biswas (2019) refer to CTSiM (CT development within STEM) and propose the STEM+CT assessment framework for middle school students using a blended methodology of formative and summative assessments.

Snow et al. (2017) assess CT in a high school CS curriculum, while Park et al. (2016) reference reading hierarchies in code as a basic CT skill (belonging to abstraction), and use three tools to assess it with university students. Rich et al. (2019) provide a framework for teaching and assessing decomposition, including strategies' employment and categorization.

CT is a cognitive process and despite the many approaches using programming does not necessarily implicate computer usage. CS Unplugged at Mines (n.d.) proposes a set of lesson plans for middle schools, based on CS Unplugged material, and Rodriguez et al. (2017) present an assessment approach of algorithmic thinking, abstraction, data representation, and pattern recognition, using rubrics and worksheets.

Allsop (2018) states that using only programming construction is insufficient for evaluating CT and proposes a multiple approach evaluation model of *computational concepts*, *metacognitive practices*, *learning behaviours,* and finally, *computer game design* when game-making is involved. She reports several findings with 11- to 12-year-old students. Wiebe et al. (2019) also refer to key cognitive abilities underlying CT that are differentiated from programming languages' knowledge.

Finally, Principled Assessment of Computational Thinking (PACT) proposes assessment design and implementation patterns for CT practices in secondary education, and provides examples of ongoing teaching projects for CT development involving STEM, games, simulations, and story-telling in AgentSheets, Alice and Scratch (Bienkowski et al. 2015).

5 Conclusions

The above results show that existing automated tools cannot assess CT autonomously and efficiently at this time. Multiple methods of assessment emerge as the more appropriate approach to CT assessment, and even researchers who introduce assessment criteria argue in favor of complementary assessments' usage (Román-González et al. 2017), while Hoover et al. (2016) indicated differences between the quantitative and qualitative analyses when using an automated tool. The safest approach for using multiple methods of CT assessment involves qualitative methods, usually using private interviews, the think-aloud protocol, and simultaneous field observation, evaluation rubrics, and students' project portfolios (Brennan and Resnick 2012; Grover 2017; Grover et al. 2014). This study reviews similar approaches as well as optimization proposals, e.g., the use of predetermined categories in content analysis and the adaptation of teacher verbal protocols in the think-aloud protocol (Lye and Koh 2014; Mueller et al. 2017). Research data converge to a similar approach using multiple methods of assessment, which shall contain formative assessment during teaching activities, and summative assessment of artifacts and students' project portfolios, although, as Mueller et al. (2017) state employing many assessment tools can be costly and onerous.

5.1 *Lack of CT Assessment Common Ground*

The lack of consensus on a unique CT definition leads to the assessment of different concepts. However, different CT assessment approaches converge to algorithmic thinking and basic programming structures, abstraction, and decomposition. This conclusion is in accordance with Araujo et al. (2016) who state that the most common CT abilities assessed include solving problems, algorithms, and abstraction, and with Cutumisu et al. (2019) who mention algorithmic thinking, abstraction, problem decomposition, logical thinking, and data. The correlation of these concepts, in terms of student's attainment has barely been researched, and there have only been a few studies, e.g., that of Rich et al. (2019) that discuss the instant that CT concepts occur and whether instances always occur together, or one CT concept could occur before another.

An answer to the lack of CT assessment approaches' common ground is the proposal that considers knowledge transfer as an essential assessment criterion, namely the students' ability to apply their knowledge and thinking processes to different contexts (Chen et al. 2017; Koh et al. 2010). Autonomous assessment approaches, such as Bebras contest, are categorized in skill transfer tools (Román-González et al. 2019), as their objective is to assess students' CT skill transferability to different kinds of problems, contexts, and situations, such as real-life problems.

5.2 *CT Assessment Implementation Age Groups*

Results indicate that most assessment approaches aim at students of higher elementary grades or middle schools, especially ones involving programming concepts' assessment. Very few studies refer to preschool education, while hardly any to adults, mainly undergraduate students. Apart from a few tools that have already been validated, most approaches are implemented with specific classes (convenient samples), and thus, even if a tool could hypothetically assess a CT dimension, it could not generally be implemented without considering the age group that it was designed for, or has been tested/validated for. Much more research needs to be conducted, using scientific documentation, in order to have tools validated for specific age groups.

5.3 CT Assessment Methods Under Prerequisites and Under Configuration

Scenarios in programming environments cannot be used efficiently, as familiarity with the software is required (Webb 2010; Werner et al. 2012). The automated assessment processes are still immature, and thus, the complementary use of assessment forms is proposed (Moreno-León et al. 2017a, b; Román-González et al. 2017). Convergent validity studies of CTt, Dr. Scratch, and selected Bebras report just partial convergence, implying that none of these tools should be used in place of any of the others, and a proper combination of them resulting in a more powerful system of assessment is suggested (Román-González et al. 2019). CT is a process and should not be evaluated as an end product, so Mueller et al. (2017) recommend formative (continuous) assessment. Hadad et al. (2019) analyze the use of continuous (informal) formative assessments in the process of CT concepts and dispositions' promotion, recognizing "instances" of guidance.

Finally, Giordano et al. (2015) state that the best practices of programming assessment's design include less emphasis on syntax, design of assessments independent from specific programming languages and use of pseudocodes, use of grading rubrics, use of gamification and competitions, and finally the validation and sharing of tools across institutions.

5.4 Reliability and Generalization Issues of CT Assessment Methodologies

Most studies' findings cannot be generalized, due to the use of small, convenient samples. Moreover, only a few of the methodologies and tools used have undergone validity and reliability checks, and additionally, some of these are limited to specific countries and populations (e.g., Dr. Scratch in Spain, CTS in Turkey), leaving open questions about their validity in other educational systems. Most studies do not use a well-defined assessment model, small samples, leading to weakness of generalization or replication and a need to improve the scientific rigor of assessments (Petri and Gresse von Wangenheim 2017). Additionally, CT studies, in general, lack in-depth analysis, and no discussion about their scientific value is usually made (Kalelioglu et al. 2016).

5.5 Connection of CT Assessment with Cognitive Skills Development

Several approaches examine the relation of CT assessment with cognitive skills' development, e.g., with the framework of intelligence CHC (Ambrósio et al. 2014; Román-González et al. 2017), or the relation between coding ability and cognitive compiling of syntax in natural language (Marinus et al. 2018). Tsarava et al. (2019) also relate CT with nonverbal visuospatial reasoning and different aspects of numeracy in younger ages. Petri and Gresse von Wangenheim (2017) report that besides evaluating the learning effects of CT in games, a wide variety of analysis factors are considered, including motivation, user experience, usability, etc. CT is also correlated with noncognitive factors, like self-efficacy and personality variables (Román-González et al. 2016, 2018a), and Basso et al. (2018) refer to nontechnical skills, such as relational skills and cognitive life-skills.

The aforementioned data make CT assessment attempts even more complicated, fortifying the arguments that using only programming constructs for CT assessment is insufficient (Allsop 2018; Wiebe et al. 2019). Perhaps, this is a reason that automated assessment in programming environments is still problematic and cannot yet autonomously and efficiently assess CT development.

5.6 Future Directions

More large-scale research of CT assessment is required, using scientifically substantiated approaches, for all age groups. In conclusion, a well-rounded CT assessment approach should consider all the previously mentioned parameters, be designed primarily for a specific age group, be implemented with a sufficient number of participants, and ensure its validity and reliability using scientific methodology, while multiple methods of assessment using qualitative approaches, field observation, and students' project portfolios, with diagnostic, formative, and summative assessment, are rated as imperative.

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The Educational Value and Impact of Serious Games in Cognitive, Social and Emotional Development in Middle Childhood: Perceptions of Teachers in Greece

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The research included in this chapter was conducted as part of the master thesis for the postgraduate degree M.Ed. from the Hellenic Open University.

1 Introduction

The term serious game first appeared in the fields of research and business in 1970 but did not become popular until after 2002 (Wilkinson 2016), as signified by the remarkable increase in the number of related publications (Çiftci 2018). Serious games are commonly defined as games that do not have entertainment as their primary purpose (Michael and Chen 2005) and are explicitly aimed at training or educating (Shute et al. 2009).

In this chapter, we focus on serious games in education. As teachers play a pivotal role in adoption of serious games in an educational context (Huizenga et al. 2017), the perceptions of teachers in Greece on the educational value of serious games and on their impact on the development of children in middle childhood are investigated. The impact of serious games on the development of children is explored with focus on middle childhood, due to the life-lasting importance of this age period (Feinstein and Bynner 2004).

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1.1 Educational Value of Serious Games

In the framework of this study, the educational value of serious games is examined under three perspectives: their effectiveness as motivation, collaboration and teaching tools.

Digital games are part of children's daily lives from a young age; thus, children today seem to be more willing to spend time learning and practicing through digital games, compared to traditional "face-to-face" teaching and pencil and paper study (Girard et al. 2013). Serious games, incorporating a variety of acoustic, tactile, visual and spiritual stimuli, allowing for multisensory learning (Papanastasiou et al. 2017), attract students' attention, stimulating their commitment and *motivation* (Bottino et al. 2014; Papanastasiou et al. 2017; Provelengios and Fesakis 2011; Zapušek et al. 2011). Notably, these positive results seem to be independent from the level of school performance of children (Bottino et al. 2014). Nevertheless, the serious game's more casual approach to learning could also account as a shortcoming, as there are still preconceptions that learning has to be painful to be effective (Prensky 2001). Finally, another disadvantage that can be attributed to the use of game-based learning in the classroom is the aspect of time, as it is not easy for the teacher to estimate the time needed for the completion of the game (Cojocariu and Boghian 2014).

The view regarding their potential as effective *collaboration tools,* which was deemed controversial in past years, nowadays shifts as serious games provide important tools for student interaction (Roffey 2009) and positive results have emerged in the research on the matter (Huang et al. 2010).

Serious games are also becoming increasingly accepted as effective *instructional tools*, even though there is little empirical data to support this, mainly due to the effect they have on motivation and the positive relation between time spent using them and learning (Girard et al. 2013). The benefits of the usage of digital games for learning compared to non-game conditions were showcased in a meta-analysis of digital games and learning research for K-16 students (Clark et al. 2016).

1.2 Impact of Serious Games on the Cognitive Development of Children in Middle Childhood

Children in middle childhood, 6–12 years old, are cognitively developing, either entering, from a Piagetian point of view, the concrete operational phase of cognitive development; acquiring new skills, such as conservation, classification, design and metacognition; or, from an information processing point of view, experiencing changes such as memory improvement, memory and post-memory strategies and increased attention control, thus setting the basis for future objective and rationalized perception of the world (Lightfoot et al. 2014). The cognitive enhancements of this period also include, among others, selective attention (Miller 1994), occurrence of working memory, shifting and planning (Best and Miller 2010).

Serious games can be a means to this end with their ability to enhance cognitive skills (Hainey et al. 2016). Their interactive nature is consistent with the current beliefs of educational psychology that active mental processing is a prerequisite for effective and sustainable learning (Wooters et al. 2013). They serve a trial and error approach, which fosters learning by doing (Papanastasiou et al. 2017), allowing for experimentation and simulation of experiences that would otherwise not be possible (Provelengios and Fesakis 2011) and of realistic scenarios in a safe environment (Wooters et al. 2013). Serious educational games can also facilitate students' engagement in academic content in a wide variety of subjects, with the transferability of in-game inquired content to more academic tasks (Papanastasiou et al. 2017). Finally, games also have the ability to provide immediate feedback about the correctness of the player's actions and to correct mistakes, giving a personalized dimension to the educational experience they offer, further enhancing the player's ability to solve problems (Wooters et al. 2013).

1.3 Impact of Serious Games on the Social and Emotional Development of Children in Middle Childhood

Middle childhood is an important time for children's *social and emotional development*, as they spend less time at home, their social interactions expand beyond the family circle and school and interaction with peers play a primary role (Lightfoot et al. 2014). Social and emotional learning is more complicated by nature as it not only may be focused on skills development and knowledge acquisition, as other subjects, but also emphasizes on changes in attitudes, beliefs, values and behaviours (Roffey 2009). The Collaborative for Academic, Social, and Emotional Learning defined five areas of social and emotional learning: self-awareness, self-management, responsible decision-making, relationship skills and social awareness (Schonert-Reichl et al. 2017).

Shifting away from the once popular belief on the correlation of games and violence, which only got inconclusive evidence (Freitas 2018), serious games seem to offer wide opportunities for social and emotional learning. They allow for transformational learning through social interaction, social connection and collaboration (Roffey 2009). Serious games have been also used as a response to the growing need to raise awareness on important social issues (Pereira et al. 2012; Schreiner 2008), in the case of awareness-raising games; to change people's views on a social issue and their real-world behaviour around it, in the case of transformation games; and to promote an idea or view on a social issue, in the case of social commentary/art games (Schreiner 2008). There is also evidence of their potential use in children's moral development (Hodhod et al. 2009).

1.4 Teacher's Perceptions on Serious Games

Despite the aforementioned encouraging research data, research done in various countries in the world on the perceptions of teachers about serious games has resulted in different levels of acceptance and perceived usefulness, in some cases more moderate (Bourgonjon et al. 2013) and in some cases more encouraging (Noraddin and Kian 2015; Sandford et al. 2006; Wastiau et al. 2009).

The present study investigated the perceptions of teachers in Greece on serious games. Despite the fact that research trends indicate that teachers play an important role in the adoption of serious games, to the best of our knowledge, this is the first quantitative study about this subject conducted among primary school teachers in Greece. It thus provides a unique opportunity to depict the current situation in the country and bring up the challenges and opportunities, enabling comparison with other countries.

In addition, the present study addressed factors that may affect teachers' views, specifically studying the role of teachers' experience and ICT skills. In the research of Ghaith and Yaghi (1997), teachers' experience has been found to be negatively correlated with the implementation of instructional innovation. Teachers with more years of experience will most probably belong to older age groups. And age has been found to have a moderating effect on perceived ease of use and perceived usefulness of educational video games (Sánchez-Mena et al. 2017), thus adding more evidence on the moderating role of experience on the perceptions of teachers about serious games. Previous research also indicates a positive correlation between ICT use and teachers' ICT competences (Buabeng-Andoh 2012). Teachers with computer use experience were more prepared to use ICT in their classes than the ones who did not have any computer use experience (Petrogiannis 2010).

1.5 Hypotheses

The theoretical analysis that preceded led to the formation of the following hypotheses for our research:

Hypothesis 1: We expect the use of serious games by teachers to be positively correlated with the perceived educational value of serious games as motivational tools, as instruction tools and as collaboration tools.

Hypothesis 2: We expect the use of serious games by teachers to be positively correlated with the perceived impact of serious games on cognitive development and on social and emotional development of children in middle childhood.

Hypothesis 3: We expect the perceived impact of serious games on cognitive development to be positively correlated with their perceived impact on social and emotional development of children in middle childhood.

Hypothesis 4: We expect teachers' experience to be negatively correlated with serious game usage.

Hypothesis 5: We expect teachers' experience to be negatively correlated with their perceptions on the educational value of serious games and the impact of serious games on the development of children in middle childhood.
Hypothesis 6: We expect teachers' ICT skills to be positively correlated with serious game usage.
Hypothesis 7: We expect teachers' ICT skills to be positively correlated with their perceptions on the educational value of serious games and the impact of serious games on the development of children in middle childhood.

2 Methodology

2.1 Research Design

The *scope* of this research was to study the perceptions of Greek teachers on the impact of serious games on cognitive, social and emotional development of children in middle childhood and on their educational value and the mediating effect of teacher's digital skills and age. To the best of our knowledge, this is the first quantitative study on the use of serious games by primary school teachers conducted in Greece. Additionally, this research depicts current status of serious game use in Greek schools, collecting data on teachers' attitude towards serious games, frequency of serious games use, reasons for use and perceived barriers to their application (Fig. 1).

A quantitative *research design* was followed, to allow for highlighting general trends and to study the relationships between the variables (Creswell 2016). More specifically a cross-sectional study research type was applied due to its suitability for researching opinions and attitudes of specific groups on an area of interest or a topic (Fraenkel and Wallen 2007).

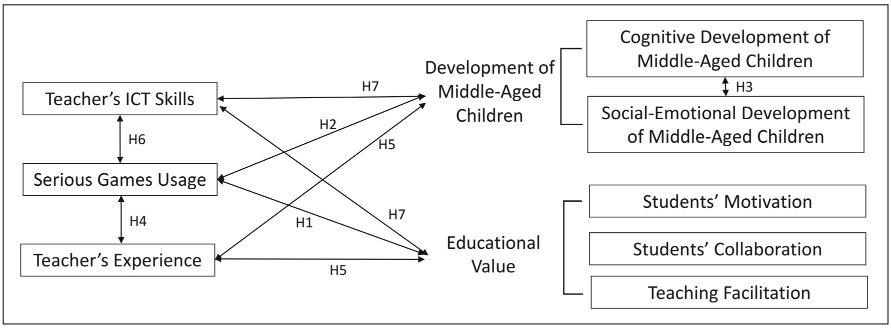

Fig. 1 Research model

2.2 Research Tool

A structured electronic questionnaire was developed as a research tool for the purpose of this study. The questionnaire was based on a review conducted on international publications in the area, in order to ensure reliability and comparability of the results. The questionnaire was comprised of five sections.

The first section included demographics. In the second section, *digital skills* of respondents were explored with a self-evaluation on the levels of technological literacy, internet literacy and digital literacy, adapted from the tool developed by Son et al. (2017) with a 5-point Likert scale, and a question on training received on the use of ICT. The *use of serious games* was investigated with a question on teaching experience with serious games. *Attitude* towards serious games was measured with five items adapted from the tool developed by An and Cao (2017).

In the third section, *perceived impact of serious games on development* of children in middle childhood was measured for the three areas, namely, children's cognitive development, children's social development and children's emotional development, with a semantic differential scale. The second question was developed based on the study of the relevant literature that preceded and concerns the impact of serious games on the development of cognitive, emotional and social skills. A 5-point Likert scale was used.

The fourth section focuses on the *educational value* of serious games. It consists of four questions. The first question was adapted from the tool developed by Allsop and Jesse (2015). In the next question, statements 1 to 10 have been adapted from the tool developed by Noraddin and Kian (2015) for their research with teachers in Malaysia. Specifically, items 1 to 4 explore the use of serious games as motivational tools, statements 5 to 10 their use as instructional tools and statements 18 to 19 their use as a tool of cooperation. Statements 11 to 15 address teachers' concerns about serious purpose games and have been adapted from An and Cao's tool (2017). All items were rated on a 5-point Likert scale.

The fifth section deals with the *barriers* that teachers identify in using serious games in the classroom. Seven items on the list were drawn from Allsop and Jesse's tool (2015), and two items were drawn from Razak et al.'s (2012) tool.

A definition of serious games in education was provided in the introduction of the questionnaire and repeated on the top of each section.

The internal consistency of each scale was assessed performing a reliability analysis. For this aim, we used Cronbach's alpha coefficient, with all scales scoring above 0.7, which indicates a high reliability.

2.3 Participants

Non-probability sampling and specifically convenience sampling were used, as participants were selected on the basis of their willingness and availability to

Table 1 Participants' age group

≤30	31–40	41–50	51–60	≥61
27.3%	30%	15%	25%	2.7%

Table 2 Participants' years of experience

0–5	6–10	11–15	16–20	20+
29.1%	12.7%	15.5%	12.7%	30%

participate in the survey, provided that they met the criterion of being primary education teachers in active employment. Calls for participation were handed via social media and emails.

The study involved 110 ($n = 110$) primary school teachers in active employment, including general teachers (63,6%; $n = 70$), special education teachers (20.9%; $n = 23$), subject teachers (6.4%; $n = 7$) and teachers holding managerial positions (9.1%; $n = 10$). It thus fulfilled the criterion of Fraenkel and Wallen (2007), who set 100 participants as the minimum sample size for descriptive studies.

The percentage of women respondents was 76% ($n = 84$), and 24% of the respondents were men ($n = 26$). These sample statistics correspond to those recorded for teachers in primary education by the Hellenic Statistical Authority in 2018 (Table 1).

All age groups were represented in our surveys' sample, with a higher participation of the generation defined by Prensky (2001) as "digital natives" (Table 2).

With regard to *highest degree attainment* of the sample, 50% of the participating teachers had only one degree ($n = 55$), 9% also had a second degree ($n = 10$), 40% had a postgraduate degree ($n = 44$), and less than 1% had a doctorate degree ($n = 1$).

Finally, a total of 61% ($n = 67$) of the respondents were working in an urban *area*, 29% in a semi-urban area ($n = 32$) and 10% in a rural area ($n = 11$).

3 Results

3.1 Use of Serious Games: Attitudes Towards Serious Games

3.1.1 Use of Serious Games

A high prevalence in the *use* of serious games was recorded, with 83.6% of the participants stating that they have used serious games at least once in the classroom. Nevertheless, despite widespread use among Greek teachers, frequency of use was found to be lower, with only 24.5% of the participants stating that they use serious games in classroom more than once a month. Interestingly enough, in the subcategory of special education teachers, this percentage is 34.8%, displaying a significant increase from the general average (Table 3).

Table 3 Frequency of serious games use

Never	1–2 times in total	3–10 times in total	Once per moth	More than once per month
16.4%	20.9%	28.2%	10%	24.5%

3.1.2 Reasons for Considering the Use of Serious Games

Regarding the *reasons* for possible usage of serious games, participant answers are of particular interest, with the most popular being the provision of learning incentives (77.5%; $n = 82$). This is followed by the improvement of learning in specific subjects, such as mathematics or language (67.3%; $n = 74$), the development of higher level technological skills (60%; $n = 66$) and developing problem-solving and critical thinking skills (60%; $n = 66$). Fewer teachers indicated as possible reasons for use of serious games their utilization as a reward (46.4%; $n = 51$) and to encourage creativity (46.4%; $n = 51$), the provision of opportunities for collaborative work (45.5%; $n = 50$) and that pupils can work independently (34.1%; $n = 38$).

3.1.3 Barriers to the Use of Serious Games

With regard to reported barriers on the use of serious games, the lack of ICT in schools (82.7%; $n = 91$) and access to equipment in the classroom (81.8%; $n = 90$) are at the forefront, followed by the knowledge of the subject of serious game by teachers (69.9%; $n = 67$) and lack of time needed to cover the designated curriculum (57.3%; $n = 63$). Other barriers that gathered high percentages are the attitude of teachers (52.7%; $n = 58$), preparation time (41.8%; $n = 46$), class management issues (40%; $n = 44$), difficulty in finding a suitable game (36.4%; $n = 40$), relevance to the curriculum (30.9%; $n = 34$), issues related to evaluating learning with games (30%; $n = 33$) and students' attitude (16.4%; $n = 18$).

3.1.4 Attitude Towards Serious Games

Teachers' *attitude* towards serious games seems to be positive, with 54.5% of them stating that they feel interested in utilizing serious games in the classroom, 21.8% enthusiastic and 16.4% comfortable. Only 7.3% stated that they do not know how to utilize serious games in the teaching process and none that he or she was against the use of serious games in class.

Table 4 Descriptive statistics for perceived educational value

	1	2	3
1. Motivation tool	1		
2. Instructional tool	**0.811**[a]	1	
3. Collaboration tool	**0.577**[a]	**0.595**[a]	1

[a]Correlation is significant at the 0.01 level (two-tailed)

3.2 Perceived Educational Value of Serious Games

The *perceived educational value* of serious games was rated positively by participating teachers, receiving an average score of 3.88 in a 1 to 5 range. Comparing the three areas used to evaluate the educational value of serious games, their use as a motivational tool was rated slightly higher ($M = 4.03$, $SD = 0.635$), followed by their use as an instructional tool ($M = 4.01$, $SD = 0.630$), while their use as collaboration tool was rated lower ($M = 3.59$, $SD = 0.772$).

As depicted in Table 4, there is a positive correlation among perceived educational value as a motivation tool and as an instructional tool ($r = 0.811$, $p < 0.0005$), among perceived educational value as a motivation tool and as a collaboration tool ($r = 0.577$, $p < 0.0005$) and among perceived educational value as a collaboration tool and as an instructional tool ($r = 0.595$, $p < 0.0005$).

Furthermore, there was a positive correlation between serious game usage and perceived value of serious games as motivation tools ($r = 0.269$, $p = 0.004$), serious game usage and perceived value as instructional tools ($r = 0.293$, $p = 0.002$) and serious game usage and perceived value as collaboration tools ($r = 0.293$, $p = 0.002$).

To further analyse the above results, an independent samples t-test was conducted to compare the perceived value of serious games as motivation tools for teachers who have never utilized serious games in their classroom and teachers who have used them at least once. There was a significant difference in scores for teachers with no serious game usage (M = 3.71, SD = 0.867) and teachers with serious game usage (M = 4.10, SD = 0.563; t (108) = −2.42, p = 0.017, two-tailed). There was a difference in the means (mean difference = −0.387, 95% CI: −0.704 to −0.07).

Likewise the t-test conducted to compare the perceived value of serious games as instructional tools for these two categories of teachers showed again a significant difference in scores for teachers with no serious game usage ($M = 3.69$, SD = 0.856) and teachers with serious game usage ($M = 4.08$, $SD = 0.574$; t (108) = −2.36, $p = 0.02$, two-tailed). There was a difference in the means (mean difference = −0.382, 95% CI: −0.702 to −0.061).

Finally the same pattern was also confirmed in the t-test to compare the perceived value of serious games as collaboration tools, which showed teachers with no serious game usage ($M = 3.17$, $SD = 0.939$) and teachers with serious game usage ($M = 3.67$, $SD = 0.712$; t (108) = −2.59, $p = 0.012$, two-tailed). There was a difference in the means (mean difference = −0.502, 95% CI: −0.886 to −0.117).

Table 5 Descriptive statistics for development

	1	2
1. Cognitive development.	1	
2. Social-emotional development	**0.695**[a]	1

[a]Correlation is significant at the 0.01 level (two-tailed)

3.3 *Perceived Effect of Serious Games on Cognitive and Social-Emotional Development of Children in Middle Childhood*

Teachers' perceptions regarding the effect of serious games on the development of children in middle childhood were also positive, receiving an average score of 3.73 in a 1 to 5 range. Their effect on cognitive development was assessed as slightly more positive ($M = 4.00$, $SD = 0.621$) than their effect on social-emotional development ($M = 3.46$, $SD = 0.775$) (Table 5).

There was a positive correlation between perceived effect of serious games on cognitive development of children in middle childhood and their social-emotional development ($r = 0.695$, $p < 0.0005$), with high ratings of the effect of serious games on cognitive development being associated with high ratings of their effect on social-emotional development.

The next issue that was explored was whether the experience of using serious games influences teachers' perceptions on the impact that they have on children's development. Indeed, there was a statistically significant positive correlation between serious game use and perceived effect of serious games on cognitive development of children in middle childhood ($r = 0.333$, $p < 0.0005$) and on social-emotional development ($r = 0.210$, $p = 0.028$).

Independent samples t-tests were conducted to compare the perceived effect of serious games on children's development for teachers who have never utilized serious games in their classroom and teachers who have used them at least once. For cognitive development, there was a significant difference in scores for teachers with no serious game usage ($M = 3.70$, $SD = 0.835$) and teachers with serious game usage ($M = 4.06$, SD $= 0.556$; $t\ (108) = -2.31$, $p = 0.023$, two-tailed), with a difference in the means (mean difference $= -0.363$, 95% CI: -0.674 to -0.052). For social-emotional development on the other hand, there was no significant difference among the two groups, teachers with no serious game usage ($M = 3.26$, $SD = 0.929$) and teachers with serious game usage ($M = 3.49$, $SD = 0.741$; t $(108) = -1.16$, $p = 0.25$, two-tailed), and no significant difference in the means (mean difference $= -0.232$, 95% CI: -0.714 to -0.250).

3.4 *The Role of Teachers' Years of Experience and ICT Skills*

3.4.1 Teachers' Years of Experience and Serious Game Usage

The relationship between teachers' years of experience and serious game usage was investigated using Pearson product-moment correlation coefficient. Correlation of the two variables was found to be very low ($r = -0.113$, $p = 0.239$).

3.4.2 Teachers' Years of Experience and Perceived Educational Value of Serious Games

In this case only the foreseen negative correlation direction was confirmed, as correlation among teacher's years of experience and perceived educational value was very low, for all three areas in which educational value was analysed, serious games as motivational tools ($r = -0.145$, $p = 0.130$), serious games as an instructional tool ($r = -0.099$, $p = 0.305$) and serious games as a collaboration tool ($r = -0.035$, $p = 0.714$).

3.4.3 Teachers' Years of Experience and Perceived Effect on the Development of Children in Middle Childhood

Correlation among teachers' years of experience and both perceived effect on children's cognitive development ($r = -0.100$, $p = 0.298$) and children's social and emotional development ($r = -0.060$, $p = 0.535$) was not confirmed.

3.4.4 Teachers' ICT Skills and Serious Game Usage

There was a positive correlation between the self-reported *ICT skills* and *serious game usage*, $r = 0.345$, $p < 0.0005$, with high levels of self-reported ICT skills associated with higher levels of serious game usage. Analysing the three items comprising ICT skills, correlation was slightly higher among *technological* and serious game usage ($r = 0.390$, $p < 0.0005$) than among internet literacy and serious game usage ($r = 0.291 = 110$, $p < 0.0005$) and among digital literacy and serious game usage ($r = 0.262$, $n = 110$, $p < 0.0005$).

Furthermore, a positive statically significant at the 0.01 level (two-tailed) relationship was found among having received an ICT training and serious game usage ($r = 0.296$, $n = 110$, $p = 0.02$), depicted in graph 1. Interestingly, 41% of the teachers who have never received an ICT training have also never used serious games in their classroom (Fig. 2).

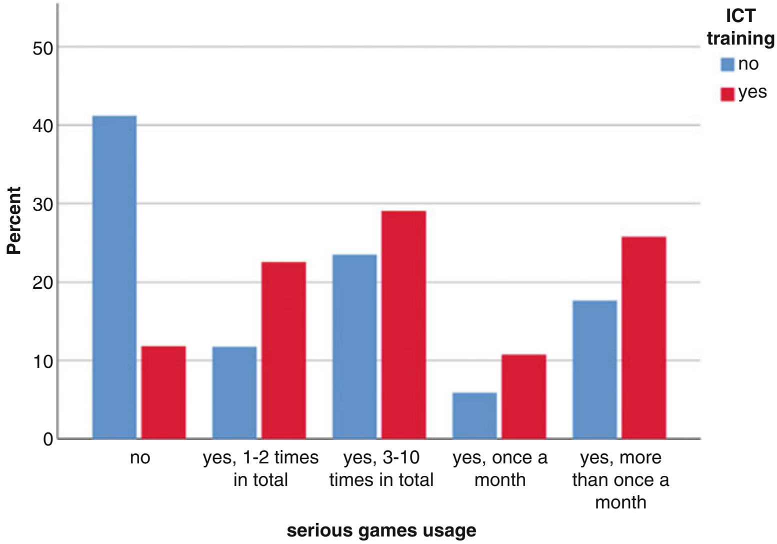

Fig. 2 Serious game usage and ICT training

3.4.5 Teachers' ICT Skills and Perceived Educational Value of Serious Games

The relationship between self-reported *ICT skills* and *perceived educational value of serious games* was also investigated using Pearson product-moment correlation coefficient, and a borderline statistically significant positive correlation was found for all three areas comprising educational value, their use as motivational tool, as instructional tool and as collaboration tool.

3.4.6 Teachers' ICT Skills and Perceived Effect of Serious Games on Children's Development in Middle Childhood

As depicted in Table 6, a statistically significant positive relationship was found among teachers' self-reported *ICT skills and the perceived effect of serious games on children's development* in middle childhood*, for both their cognitive and social-emotional development* (Table 7).

4 Discussion and Conclusions

In this chapter, a study about the use of serious games in primary schools in Greece was presented, focusing on the perceptions of primary school teachers on

Table 6 ICT skills and perceived educational value correlation

		ICT skills
Motivation tool	Pearson correlation	0.285[a]
	Sig. (two-tailed)	0.003
	N	110
Instructional tool	Pearson correlation	0.267[a]
	Sig. (two-tailed)	0.005
	N	110
Collaboration tool	Pearson correlation	0.293[a]
	Sig. (two-tailed)	0.002
	N	110

[a]Correlation is significant at the 0.01 level (two-tailed)

Table 7 ICT skills and perceived effect on development

		ICT skills
Cognitive development	Pearson correlation	0.**321[a]**
	Sig. (two-tailed)	0.001
	N	110
Social-emotional development	Pearson correlation	0.268[a]
	Sig. (two-tailed)	0.005
	N	110

[a]Correlation is significant at the 0.01 level (two-tailed)

the educational value of serious games and their effect on children's development in middle childhood.

Findings suggest that the *use of serious games* in the classroom is quite widespread, with 84% of the participating primary education teachers having used serious games in the classroom. Comparing with the findings of Allsop and Jesse (2015), results indicate that 89% of the teachers in the UK and 61% of the teachers in Italy participating in their survey have used digital games for teaching. The motivational power of games was deemed the most popular reason for considering the use of serious games, with the participating teachers in Greece having similar opinion on this point with primary education teachers in Italy and the UK who participated in the study of Allsop and Jesse (2015). The most important differentiations among the two studies were the development of higher-level technological skills as a reason for serious game usage and their use as a reward. These answers were third and fifth most popular reasons to use in our study, respectively, but were selected by a significantly lower percentage of teachers in Italy and in the UK (Allsop and Jesse 2015). Comparing the findings of the two studies with regard to barriers to the use of serious games, the most important differentiation seems to be the one regarding the lack of ICT capabilities in schools. While it is listed as the most popular barrier among Greek teachers, it is listed only fourth more important barrier by Italian teachers and third more important barrier by UK teachers. Regarding similarities and common tendencies in all three countries, access to equipment in the classroom is rated high in all cases (first place in Italy and the UK and second place in Greece), thus highlighting the importance of the existence of the necessary technological equipment in schools for the utilization of serious games. Students' attitude is also listed last in all three countries, receiving a significantly lower percentage than other barriers.

According to our study, primary teachers in Greece have a positive attitude towards serious games, and participants on average evaluated positively their *educational value*, as a motivational tool, as an instructional tool and as a collaboration tool. There was a significant difference in scores for teachers with no serious game usage and teachers who had used serious games at least once in all three cases and a positive correlation among serious game use and perceived educational value of serious games as motivational tools, as instruction tools and as collaboration tools, thus confirming Hypothesis 1.

The teachers participating in our study also positively rated on average the *effect of serious games on children's development* in middle childhood, both for their cognitive development and for their social-emotional development. Perceived impact of serious games on cognitive development was positively correlated with their perceived impact on social and emotional development of children, thus confirming Hypothesis 3. The use of serious games was found to be positively correlated with both the perceived impact of serious games on cognitive development and on social-emotional development. Hypothesis 2 was thus confirmed for the case of cognitive development and for the case of social-emotional development.

The results were hence positive both for their educational value and for their impact on development in middle childhood. Nevertheless, it is notable that teachers appeared to be more sceptical about the use of serious games as collaboration tools and their effects on social-emotional development. A possible explanation for this might be the limited availability of serious games that focus on these aspects, or possibly, it could be linked to remnants of the, now discredited, association of video games with antisocial and violent behaviours. Furthermore, the overall encouraging findings of our study should be interpreted carefully. The deception that serious games can act as a panacea for motivation needs to be avoided (Charsky 2010). Not all serious games have the potential of realizing the benefits described in the literature, and teachers need to be made aware of these restrictions. The important role of design beyond medium has to be taken into account (Clark et al. 2016), as the potential teaching value of serious games relies heavily in maintaining the balance between game mechanics, such as competition, goals, rules, challenges, choices and fantasy, and pedagogical elements, achieving thus an equilibrium among fun and learning (Charsky 2010; Pereira et al. 2012). It cannot be any serious game; it has to be the correct game. More than one in three teachers participating in our study seem to agree on that, as they note the difficulty of finding the right game as a barrier for the utilization of serious games.

Another area of interest for our study was the role of teachers' years of *experience* and *ICT skills* and how they would affect serious game use and their perceptions on serious games. Both our hypotheses related to teachers' experience were rejected, as no significant correlation was found neither among teachers' experience and serious game use, as indicated in Hypothesis 4, nor among teachers' experience and perceptions on the educational value of serious games and their impact on children's development, as indicated in Hypothesis 5. On the contrary, both hypotheses related to the role of teachers' ICT skills were confirmed, as *they were found to be positively correlated with serious game usage, as* indicated in Hypothesis 6, and also positively correlated with their perceptions on the educational value of serious games and the impact of serious games on the development of children in middle childhood, as indicated in Hypothesis 7. This is in line with the findings of the study of Noraddin and Kian (2015).

This study, by defining the barriers that teachers see in the utilization of serious games, can provide some insight about the development of policies to increase the use of serious games as educational tool in the class setting. In line with this, an interesting finding of this survey is the importance of teacher training in the utilization of serious games. On one hand, teachers who evaluate their ICT skills higher were more probable to use serious games in their classroom, and on the other hand, almost 70% of the teachers participating in the survey stated that (the lack of) knowledge of the subject of serious game by teachers is a barrier to the utilization of serious games. The effective utilization of games and implementation of game-based learning in the classroom imply that teachers must uptake a different role (Allsop and Jesse 2015; Sandford et al. 2006). Thus, training could not only help them overcome this barrier but also prepare them to adapt their role appropriately, when utilizing serious games, in order to reach their full potential. Furthermore, the important role of ICT equipment in schools was highlighted via this study. More than 80% of the participating teachers identified lack of ICT equipment in schools and in the classroom as barriers to the utilization of serious games, thus highlighting the need for investment in the technological equipment of schools.

Regarding the limitations of this study, one area of future interest could be the development and validation of an appropriate research tool in the Greek language. Further limitations of this study stem mostly from the nature of the research carried out, which provides a static picture of teachers' views on the subject, at the time of the survey. It thus fails to capture the dynamics of the formation of these views and their differentiation over time. It would therefore be of interest for future research to carry out a longitudinal study based on the design and findings of the present. Additionally, cross-country comparative studies based on similar research protocols could provide the basis for development of taxonomies and promote research in the field.

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A Framework Proposal for Interdisciplinary Early Childhood Education Integrating ICT and Foreign Language

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1 Introduction

1.1 Literature Review on Integrating ICTs with Teaching and Learning

Being literate today is not just about being able to read and write; the twenty-first-century learner lives in a world of technology and innovation where the challenge for digital literacy is calling for a transformation of pedagogy. In that social context, it is often observed that education is bound to change if learning is to meet the challenges and opportunities of the mobile age (Yelland and Gilbert 2013). It is therefore evident why technology constitutes one of the main axes of reformed curricula, being integrated into them as a means for improved instruction and successful learning outcomes. The need for Information and communication technologies (ICTs) is not exclusive to learners of a particular age group; researchers have highlighted the impact of using multimedia as innovative tools for early childhood education learners (Sarrab et al. 2012). Recognizing the importance of digital skills for young learners, significant work has been carried out towards the development and measurement of such skills during the past few years (Digital Skill Indicator 2016).

Focusing on young learners and the utilization of ICTs in the classroom special emphasis has often been placed on the concept of 'gamefulness' as a defining quality of a game. In a gameful environment, the learner-player engages in a learning activity-game, where the educational goals are achieved by playing and following certain rules, referred to as game mechanics. However, critical design or evaluation

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of educational games should precede their implementation in class. Habgood and Ainsworth (2011) metaphorically refer to the ‘chocolate-covered broccoli’ problem to describe a claimed-to-be educational ‘game’, where the ‘chocolate’ game content is actually so ineffective that gives learners-players a boring feeling, like that of actually tasting ‘broccoli’.

The ‘gamification’ of learning refers to using game-like techniques in educational contexts. It has been observed that gamification: (a) engages learners and increases creative thinking (Gibson et al. 2015; Werbach and Hunter 2012) (b) motivates them or influences their behaviour (Kapp 2012) and (c) allows for the development of higher cognitive skills and supports collaboration (Browne et al. 2014; Walsh 2014). Point scoring, competition with others, challenges and rewards are employed to combine intrinsic with extrinsic motivation, so as to raise engagement (Muntean 2011). Gameful or gamified educational approaches where digital tools are employed, let children play and enhance their learning, develop their social interactions, as well as their problem-solving, memory, higher-order thinking and critical ability skills. Digital educational games are also considered as a dynamic tool for developing pupils’ cognitive skills and enhancing their learning motivation (Doliopoulou and Rizou 2012; Kokkalia et al. 2017; Plowman and Stephen 2014). Hick and Turner (2013) invite teachers to become advocates of the new ways of teaching, by embracing digital tools and by creating a technological context in class to promote learners’ digital literacy skills during language learning. Under this perspective, play can be connected to digital media and support twenty-first-century learning needs. Also, unless teachers perceive ICTs as useful tools in the educational process, they will not be willing to meaningfully integrate them in their kindergarten (Awidi and Ismail 2014). As a consequence, in this chapter, we aim to approach early childhood learning in an interdisciplinary way, integrating ICT and FL (Foreign Language). We underline the results of relevant studies having been conducted only in the Greek context since 2009, which refer to school advisors, teachers, parents and students.

This chapter is organized as follows: Initially, the theoretical background is discussed, focusing on multiliteracies development, early foreign language learning, ICTs and the educational policies and practices adopted in Europe and in Greece. Then, the literature review of the conducted research is described. The results are presented before the concluding discussion. In this last section, focus is placed on the effectiveness of an early childhood education interdisciplinary framework for achieving goals for early foreign language learning and ICTs in Kindergarten.

2 Theoretical Background

2.1 Multiliteracies and Early Foreign Language Learning

Language acquisition seems more easily accomplished at a young age, since the positive effects have been long reported to differ in degree, depending on the age of acquisition (Cummins 1979, 1991; Pinter 2017). Young learners clearly perform better in language proficiency tests (reading and writing tasks, vocabulary and oral speech acquisition) than students who start learning an FL at an older age (Gawi 2012). The ability to communicate effectively is easier for young students to acquire, since they can more easily master the structures and the phonological system in a second/foreign language (Archila-Suerte et al. 2015; Bongaerts 1999). Although the positive effects are stronger at earlier stages of instructed foreign language learning they are observed to abate in the first grades of primary school or even in kindergarten, unless they are explicitly fostered (Griva and Sivropoulou 2009; Holger et al. 2019; Maluch and Kempert 2017). Moreover, a correlation is observed between the time devoted to learning a language and the competence acquired in it (Mourão and Lourenço 2015; Pinter 2017), while bilingualism is also associated with advantages in foreign language achievement (Byalistok 2001; Bialystok et al. 2011; Maluch et al. 2016).

Among the various desired competencies listed in the 21st century skills framework (Partnership for 21st Century Skills 2011), multilingual communication, problem solving in authentic learning environments, and cross-cultural understanding are included. Moreover, the use of Information and Computer Technologies (ICTs) by young children is increasing during the last decade, mainly regarding the home environment (Stephen and Edwards 2018) while recent research highlights that integrating ICTs as dynamic teaching tools in the language classroom (Kokkalia et al. 2017; Merzifonluoglu and Gonulal 2018) can contribute to meeting the challenges and opportunities of the technologically literate young children of the mobile age (Korosidou and Bratitsis 2019a; Nikolopoulou et al. 2019). In such a context, the notion of a multiliteracies pedagogical approach through playful digital learning becomes fundamental. By identifying the educational potential of children's play with technologies, critical literacy development is encouraged. While offering opportunities for meaning–making by employing different semiotic modes the benefits of multiliteracies pedagogy for young learners' language learning and their multimodal literacy skills are observed (Kaminski 2019). Especially regarding preschoolers, technology-enhanced learning courses seem to have a great impact on their active participation in learning activities, as well as on the improvement of their FL proficiency, their phonological awareness and vocabulary acquisition (Karimkhanlooei and Seifiniya 2015). Other researchers also report similar findings in response to multimedia utilization in teaching a second/foreign language at an early age (Barone 2012).

2.2 *Early Language Learning and ICTs: Educational Policies and Practices in Europe and Greece*

Multilingualism and early foreign language learning have been of pivotal importance for the European language policy in recent decades, based on the notion *"the earlier, the better"* (Abrahamsson and Hyltenstam 2008, 2009; Cummins 2010; DeKeyser 2013 among others). With the establishment *1 + 2* of the European Council (2001) almost two decades ago, and the need for today's more than ever multilingual Europe to provide education adapted to the needs of its plurilingual citizens, responding to social and cultural needs and aims, the introduction of official second/foreign language learning within educational systems already starts from early childhood, for children aged under 6 years (Eurydice 2017: 30). Most European countries have decided to integrate compulsory early language learning programs into primary education, with English being their first choice (Pecherskikh and Shishkina 2015). European organizations have also been taking certain initiatives as far as digital skills enhancement and ICT integration in the curricula is concerned. Bratitsis et al. (2016) set a framework to prepare students face the twenty-first-century challenges and develop a number of skills to successfully handle challenges in a global community and become active citizens. Digital literacy for all (Digital Competence Framework for Citizens 2017; Digital Citizenship Education Handbook 2019) also refers to proposals responding to the challenges for education in the mobile age, focusing on the potential of digital literacy practices. Reform of curricula and transformed pedagogical practices are also considered essential, as teachers are welcomed to implement digital learning practices by designing, selecting or managing digital resources (Digital Competence Framework for Citizens 2017).

In the Greek context, from the school year 2010–2011 by the decision of the Ministry of Education and Lifelong Learning, English was introduced as an FL from the 1st Grade of Primary School, through the implementation of the pilot program 'New Foreign Language Education Policies at the School: English Learning Program in Early Childhood' (PEAP 2010). The early language learning curriculum is structured on three basic principles that determine the nature of the courses (Dendrinou et al. 2013): (a) it is aimed at children with emergent school literacy in their mother tongue (L1) and focuses on the development of social literacy in the foreign language, (b) it focuses on individualized learning through a number of age-appropriate activities and (c) it aspires at developing young learners' intercultural communication ethic. In addition, the development of social skills is recorded as equally necessary with the development of learning strategies, as well as with the development of oral speech in the English language, the enhancement of analytical and synthetic thinking skills, as well as the L1 and FL culture.

Concerning ICTs integration in kindergartens and early primary settings in Greece, the official curriculum for Kindergarten highlights the role of ICT as a learning tool. Children should get acquainted with and enhance or develop a number of ICT skills in the context of daily school activities in various topics.

Among the aims of ICTs integration is also that of understanding of the role of digital technologies in modern society and culture of the twenty-first century. All in all, knowledge of children's experiences outside the school classroom is of utmost importance in organizing activities and choosing topics which appeal to preschoolers' needs and interests, embracing a rather holistic approach (Teacher's Guide for the Kindergarten Curriculum 2014). Also, at the beginning of 2020, the Greek Ministry of Education announced its planning for integrating robotics and FL in Kindergarten through interdisciplinary projects, thus further enhancing both digital literacy and FL learning.

3 Method

3.1 Purpose of the Study

In the context of the above-mentioned background, the ultimate goal of the current study was to perform a research-synthesis on pilot implementations conducted by the researchers. It is worth mentioning that the absence of relevant research activity in Greece during the last decade led the researchers to the choice of using as data sources only the above-mentioned studies. Aiming to affect early childhood children's (mean age 5 years), literacy practices researchers integrated ICT and FL learning. Therefore, a plethora of playful, interactive activities was designed and implemented as resources for formal or informal, self-directed language learning and examined the influence of modern technologies and playful, kinaesthetic activities for language learning in the long perspective.

More specifically, the further objectives of this study were:

- To identify parents' opinions, attitudes or concerns towards early English as a foreign language (EFL) learning
- To determine preschool teachers' and advisors' beliefs and concerns regarding the introduction of English as a FL in Kindergarten
- To provide an overview of a game-based approach in early language learning settings, integrating ICT and kinaesthetic activities
- To synthesize the specific gains stemming from the creation of a playful and multimodal English as a FL early learning environment and the integration of digital learning activities in a gamified context

3.2 Data Sources

The studies were conducted in northern and southern Greece and were published in journals or collective books during the period 2009–2020 (Table 1). The literature review of the studies conducted focused on employing a game-based approach

Table 1 The conducted research literature

Study	Implementation setting and research procedure	Research instruments	Participants
Griva and Sivropoulou (2009)	A multisensory, game-based EFL learning context, where preschoolers interacted and communicated in a playful environment	Qualitative and quantitative research instruments (pre- and post-test, non-participant non-structured observations)	32 preschoolers
Griva and Sivropoulou (2010)	Reflecting on kindergarten teachers' and advisors' views related to early EFL learning, their attitudes on teaching methodologies and their concerns	Qualitative research instruments (questionnaires, semi-structured interviews)	8 school advisors, 150 preschool teachers
Griva et al. (2010)	An interactive, game-based EFL context where young learners were engaged in problem-solving and kinaesthetic activities	Qualitative and quantitative research instruments (pre- and post-test, non-participant observations, structured interviews)	50 early school-age children (experimental and control group) 4 teachers (2 of them were English language teachers)
Griva and Chouvarda (2012)	Specification of parents' perceptions of central issues on their children' s English as a foreign language learning in state schools and recording of their involvement in their children' s foreign language education	Qualitative and quantitative research instruments (semi-structured interviews)	50 parents of early school-age children
Papachristou and Bratitsis (2016)	Examining preschoolers' emotional well-being through their engagement in interactive (real and digital) physical games	Quantitative research instruments (observation, semi-structured interviews with participants)	12 preschoolers

Melliou et al. (2015)	Employing digital storytelling and visible thinking routines as a means for uncovering preschoolers' ideas of human rights and communicating them effectively to a broad audience	Qualitative research instruments (observations, semi-structured interviews, personal interaction with the participants, analysis of the artistic, conceptual and technical aspects of kindergarteners' digital storytelling)	24 preschoolers
Moutafidou and Bratitsis (2016)	Examining the contribution of interactive activities to children's understanding of the concept of culture and their ability to express ideas by creating a digital story	Qualitative research instruments (teacher/researcher's journal, interviews with participants, children's portfolios)	9 preschoolers and their parents
Bratitsis (2017)	Examining Kindergarten teachers' initial beliefs on technology use, their storytelling and digital storytelling practices through their participation in a distance digital storytelling training program	Qualitative and quantitative research instruments (interviews with participants)	11 Kindergarten teachers
Griva and Korosidou (2018)	Creating a digital learning environment, where ICTs and EFL are integrated for the acquisition of basic communication skills, the enhancement of creative expression and multicultural understanding	Qualitative and quantitative research instruments (mid-term and final evaluation, teacher/researcher's journals, semi-interviews with the children, questionnaires to parents)	35 preschoolers

(continued)

Table 1 (continued)

Study	Implementation setting and research procedure	Research instruments	Participants
Korosidou and Bratitsis (2019b)	Use of mobile learning devices and multimodal material, utilizing digital storytelling and augmented reality to enhance vocabulary learning	Qualitative and quantitative research instruments (non-equivalent group post-test-only, semi-structured interviews, teacher/researcher's journal)	38 early school-age children
Korosidou and Griva (2019)	Creating a school teacher–parents partnership in order to build positive attitudes towards target language and enhance successful learning outcomes in an early childhood setting	Qualitative research instruments (questionnaires to all parents, interviews with parents of the focus groups, teacher/researcher's journal)	20 parents of preschool children and 6 parents of preschool children participating in focus groups
Korosidou and Griva (2020a)	Examining the use of games and educational technology for the development of preschoolers' EFL oral language skills and reflecting on positive attitudes towards foreign language learning and ICT	Qualitative and quantitative research instruments (Initial, mid-term and final evaluation, teacher/researcher's journal, external participant's observation records)	26 preschoolers
Korosidou and Griva (2020b)	Recording the development of skills and literacies associated with ICTs and EFL via a gamification pedagogy in a digital storytelling context where creativity, multicultural understanding and multiliteracies and digital games were inextricably interwoven	Qualitative research instruments (teacher/researcher's journal, interviews with participants)	26 preschoolers 26 first graders

and exposing very young learners to various modes of communication, aspiring to enhance their language and digital literacy skills. Interaction with ICT for educational purposes was of utmost importance, starting from the kindergarten and continuing to the early school age.

4 Results

4.1 School Advisors', Teachers' and Parents' Views on Early Childhood Learning

All stakeholders' (school advisors', teachers' and parents') views were evaluated regarding early FL learning in an interdisciplinary, multimodal context in order to design a framework and adopt teaching methods that would better accommodate preschoolers' needs and allow for improved learning outcomes. They were considered to play a key role in young children's educational achievement, since they constitute a powerful network and they can strongly impact on children's attitudes and on the successful accomplishment of the objectives set in early childhood education settings (Gaynor 2012; McDowall et al. 2017; McWayne et al. 2015; Wang and Sheikh-Khalil 2014); therefore their attitudes towards Moreover, they seem to contribute to policy decisions and determine new directions for early childhood education (Griva and Chostelidou 2011).

After collating all the above-mentioned literature (Bratitsis 2017; Griva and Chouvarda 2012; Griva et al. 2010; Griva and Sivropoulou 2009; Korosidou and Griva 2019), utilizing the corresponding qualitative and quantitative data, the following results emerged:

(i) School advisor's responses

The school advisors showed their agreement regarding early EFL learning, focusing on oral skills development. They also acknowledged the significant role of English and the benefits of early FL learning for children's cognitive development, improved overall performance and multicultural awareness raising (63%). They proposed a game-based or/and a story-based methodology, where preschoolers are provided with opportunities for movement and active participation and meaningful learning in an interdisciplinary, supportive learning environment. Concerns were expressed for children of an immigrant background, experiencing early trilingualism. Finally, the participants mainly indicated that young children should receive ample input in the EFL by well-trained kindergarten or English teachers.

(ii) Teacher's responses

(a) Positive Attitudes

The majority of the participants indicated their agreement concerning the necessity of learning English as a FL in kindergarten by focusing on oral skills development. They acknowledged: (i) the significance of the English language, (ii) language interrelations between development in one language and another/others, (iii) benefits for their cognitive and academic development, and (iv) the enhancement of their multicultural awareness. Moreover, they considered that early language learners can benefit from the 'critical period', learning the FL easier and quicker than older learners. They also proposed a game-based framework (50%) or role-playing activities (24%) in a cooperative and interactive learning environment, where children's interests are put at the core. Learning the FL through authentic and multimodal material, focusing on communicative skills development was also underlined. Furthermore, a significant number of participants (34%) stated that Kindergarten teachers with specialized knowledge in the target language should teach EFL, while others (24%) concluded that English language teachers are to teach the FL.

The majority of Kindergarten teachers were also positive towards technology use in the classroom, using various applications as supportive tools for their teaching or for searching information on a daily basis (82%). However, they less often utilize digital tools to create their own videos, to present their students' works, to record stories or narratives or to create digital comics with children. Regarding the benefits of digital storytelling, kindergarten teachers underline that the use of technology is attractive to children and increases their motivation to participate. In addition, they believe that their creativity is enhanced, their collaboration and problem-solving skills are developed, and they also have opportunities to interact with digital media.

(b) Negative attitudes and concerns

Only a small number (30%) of the participants expressed their negative attitudes towards early EFL learning, mainly supporting young learners immaturity for learning a FL or raising issues of readiness for learning the structure or the complexities of a FL. Concerns were expressed concerning immigrant children (5%), problems related to mixed ability classes (2%), the developmentally appropriate activities (2%) and time management (2%).

Regarding their digital skills and practices, Kindergarten teachers seem very insecure about their training in the field of digital storytelling. They also seem to be unaware of the primary structural elements of a story (plot, characters, scenes etc.). However, they are interested in learning about the digital storytelling approach and engaging children in digital storytelling practices.

(iii) Parent's responses

(a) Positive attitudes

More specifically, parents underlined the necessity of their children learning English as a FL from a very young age, considering that young children can learn a FL more easily and quickly. The role of playful activities and that of teachers appropriately trained to meet very young children's educational needs were also mentioned. An adapted to children's need curriculum was also mentioned to be of critical importance. The need for young children to acquire multilingual competences was also highlighted.

(b) Negative attitudes and concerns

A small number of parents stated that children may be cognitively immature to learn a FL at a very young age. Also, while men seemed to place more emphasis on the methodology used, women focused on taking into consideration the positive implications of early FL learning in plurilingual education systems.

Additionally, concerning parents' inclusion in school practices in cooperation with the school community it was found that there is a need for parental support regarding their children's first contact with a FL. Through interpersonal meetings with the teachers, parents can be constantly informed about the learning objectives and contribute to their achievement by providing appropriate assistance to their children. Focus-group discussions were also found to greatly contribute to this process. Parents were observed to be eager to be given the opportunity to get involved in their children's learning under certain preconditions. Both male (27%) and female (73%) parents stated that they would welcome feedback from teachers regarding the strategies that can be applied to let preschoolers familiarize with the FL outside the classroom, e.g. when at home. They suggested being provided with educational material, so that they can support their children's familiarization with the target language through appropriate input. Moreover, according to parents, such a process would enhance a successful language learning process and strengthen their positive attitudes towards it. Finally, the attitude of the parents towards FL, e.g. by recognizing its importance for their children's academic learning and feeling confident in the teacher and language learning program, greatly contributed to children's positive attitudes and their learning.

4.2 Very Young Children's Experiences Engaging with ICTs in FL Settings

In the conducted research studies reviewed (Bratitsis 2017; Griva and Korosidou 2018; Korosidou and Bratitsis 2019b; Korosidou and Griva 2020a, b; Griva and Sivropoulou 2009; Griva et al. 2010; Melliou et al. 2015; Papachristou & Bratitsis), the scholars initially studied the objectives included in the 'Preschool Teacher Guide' (2006) and following on the 'Teacher Guide for the Kindergarten Curriculum' (2014) with the aim of creating a coherent and cohesive interdisciplinary framework. The purpose and objectives of PEAP (2010) also provided a theoretical and methodological support that enhanced the understanding and support of the principles upon which the Program of Studies for early foreign language learning is based.

In the current study, for the purposes of coding, the literature results focusing on children's needs and interests, as well as on learning outcomes obtained when ICTs, foreign language and physical education are integrated, 'less open and more directed focused coding process' were taken into account, as reported by Charmaz (2006, pp. 46, 57). Initially, 'the most common or most important key codes' (Saldaña 2016, p. 264) were identified, which led to the definition of the categories (Table 2). Then the relevant frequencies were noted for each of the above-mentioned conducted research studies (9 research studies in total). Following on, the structured subcategories were created, giving a brief description of the content of all the data collected. The categories, subcategories and the relevant frequencies are shown in Table 2.

Analysing the data presented in Table 2, it is observed that language acquisition was integrated with other disciplines, creating links to Literature, Physical Education and ICT. The strands that constituted the pilot framework were developed around communication, technology, art and culture and connections made with the other disciplinary areas for the acquisition of oral language skills. Children of the preschool or early school age were provided with opportunities to interact with peers in a pleasurable and playful way, utilizing both digital means and physical objects.

Drawing on scholars' observations (Singelton and Ryan 2005; Muñoz 2006) who have argued that young children can effortlessly acquire a second language at a young age due to their immersion in rich language environments and appropriate input provided, the research reviewed focused on providing developmentally appropriate, rich multimodal input. More particularly, learners were encouraged to:

- Use digital tools and acquire digital literacies and language skills, through approaches triggering an understanding of the social parameters that shape communication
- Interact with computers, tablets and interactive whiteboards to participate in digital storytelling (DS) processes, as well as use digital cameras to participate in re-telling the story activities
- Use the power of ICT tools to share products with an authentic audience and develop citizenship awareness
- Use target language for a purpose, communicating in groups or during role play and dramatizations in an interdisciplinary learning context
- Play online educational games, get involved in augmented reality and educational robotics activities and in kinaesthetic games, therefore learning through play and interaction
- Engage in creative activities that responded to their curiosity and imagination by simulating their online experiences
- Engage in physical activities, where they were provided with opportunities for emotional well-being development, as well as verbal communication and social skills enhancement.

Table 2 Categories, subcategories and frequencies in the research studies analysed

Category	Subcategory	Frequency
Learning stage	1. Kindergarten	6
	2. Early school years	2
	3. Mixed	1
Intervention duration	1. $\geq$ 2 months	4
	2. > 6 months	1
	3. $\leq$ 1 school year	3
	4. $\leq$ 2 school years	1
Number of sessions	1. 1 h session/twice per week	4
	2. $\geq$ 1 h session/twice per week	1
	3. $\geq$ 2 h session/twice per week	1
	4. 1 h session/4 times per week	3
Teaching approaches	1. Game-based learning	7
	2. Computer-assisted learning	5
	3. Gamification of learning	7
	4. Digital Storytelling	5
	5. Task-based learning	7
	6. Cooperative learning	7
	7. Problem-solving	6
	8. Visible-thinking routines	3
Learning activities	1. Activities with digital media	7
	2. Creative activities	8
	3. Kinaesthetic activities	7
	4. Experiential activities	5
Children's attitudes	1. Verbal communication	8
	2. Non- verbal communication	8
	3. Engaging in digital activities	7
	4. Engaging in physical activities	7
	5. Engaging in creative activities	8
	6. Target vocabulary acquisition	6
	7. Showing commitment	7
	8. Learning in a pleasurable way	8
	9. Interaction with peers	8
	10. Intercultural awareness raising	6
	11. Citizenship awareness raising	3
Hardware utilized	1. Computers	6
	2. Tablets	4
	3. Interactive whiteboard	4
	4. Video game consoles	1
	5. Floor roamers	4

(continued)

Table 2 (continued)

Category	Subcategory	Frequency
Multimedia visual aids and tools	1. Educational games	7
	2. Digital games	7
	3. Interactive flashcards	5
	4. e-books	5
	5. Augmented Reality technology	3
	6. QR codes	1
	7. Digital maps, digital posters, digital puzzles	7
	8. Digital art software	4
	9. Authentic videos	3

5 The Proposed Framework

Drawing on the abovementioned, we propose an interdisciplinary framework (Fig. 1) for early childhood education, which sets specific guidelines to be taken into consideration when designing and implementing early childhood programs. The framework develops upon ICTs and Foreign Language, creating links among them and the parental involvement factor, in a game-based, playful and cooperative environment.

In such a context our attention was focused on certain needs, specifically: (a) teaching delivery by computer-literate education teachers, specialized in the field of early foreign language learning/teaching and in the early childhood pedagogy by attending pre-graduate courses or in-service training programs, (b) provision of a game-based curriculum, as well as digital tools and materials that suit the needs of very young children in an educational context, (c) strong cooperation and communication partnerships among parents, school and children.

5.1 Leveraging the Pedagogical Effects by Creating a Game-Based and Multimodal Early Language Learning Setting

Parameters such as the quality, quantity and frequency of the language input appear to significantly contribute to children's language ability (Cartmill et al. 2013; Goldin-Meadow et al. 2014; Hirsh-Pasek et al. 2015; Pfenniger and Singleton 2017). The observations of this study come into agreement with the previous research, placing special emphasis on the need for the introduction of a playful and multimodal early learning environment where young children have ample opportunities to act in a gamified context where language learning activities, physical activities and ICTs are substantially integrated. Digital games with preschool children also lead to successful vocabulary learning, activating their interest and their commitment to

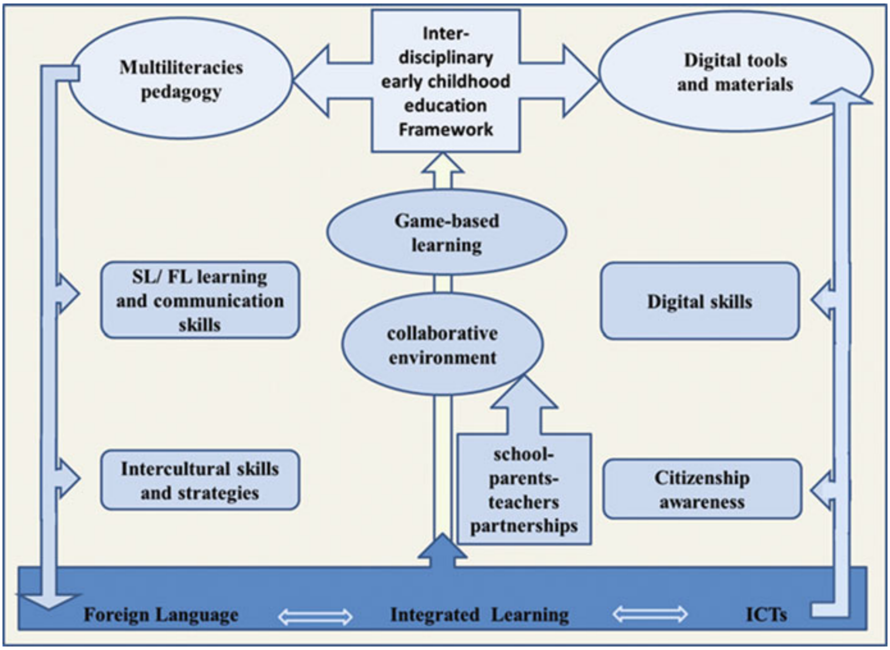

Fig. 1 The interdisciplinary framework

the learning process. Digital applications used in education are proven to enable children acquire vocabulary in the target language and become familiar with its use (Paluka and Collins 2015; Shelby-Caffey et al. 2014), while multimedia features of a technology-enhanced language learning environment also have a positive influence on young children's motivation (Bus et al. 2015), their pronunciation and speaking skills (Gilakjani and Ahmadi 2011).

In such a context, it is observed that DS can activate children's interest in learning, challenge their creativity and enhance digital literacy skills (Frazel 2010; Miller 2010). When DS is combined with experiential and motor activities, it can activate children's motivation and have a positive effect on target vocabulary learning, as well as on target language comprehension (Loniza et al. 2018). Also, especially in terms of preschool, it is emphasized that dialogue reading and storytelling can contribute significantly to the development of children's vocabulary (Macy 2016), while the combination of narration and playful activities has positive effects on language learning, even for preschoolers (Toub et al. 2018). Moreover, target language vocabulary recycling in a variety of contexts allows for frequent exposure to it, while the use of technology lets very young learners familiarize with EFL having a positive effect on their language skills (Cutter 2015). Therefore, DS constitutes a potent tool or 'a more appealing than physical storytelling, multi-sensory mean' for preschoolers with implications for their linguistic, cognitive and emotional development (Bratitsis 2018; Stamatis and Ntouka 2018), as well as children's involvement in the process and the effectiveness of initiatives against major social issues (Konstantopoulou et al. 2018). Exposure to target vocabulary and stereotypical expressions through narratives enables children to easily learn them, while also creating opportunities for occasional learning of technology-related vocabulary when interacting with digital means. The current study underlines that successful learning outcomes can be attained especially if DS is established in the central axes of curriculum allowing for the integration of a number of interrelated and interactive digital and physical activities to strengthen young learner's twenty-first-century skills.

However, the quality of teaching relies upon the successful use of technology through careful design, implementation of effective activities and selection of appropriate technological tools to achieve learning objectives. Regarding the implication of gamification techniques, it also needs to be stated that if the content is not in itself compelling and of high value, then adding gamification will produce few or no results (Kapp et al. 2014).

5.2 Empowering School Teachers-Parents Partnerships

Developing a partnership among school teachers-parents and empowering their collaboration can help build parents' positive attitudes and enhance their early childhood children's performance. Exploring the needs of parents and examining the factors that influence their views and their involvement in their children's learning during the implementation of early childhood programs allows for structuring specific proposals for the implementation of activities that can enhance learning outcomes. Following on, strong ties between parental involvement and children's academic and behavioural success may contribute to children's high performance (Berthelsen and Walker 2008). According to the results of the present study, parents are positive towards the introduction of early FL programs and ICTs. The most effective methods of strengthening their involvement are the ability to express and record the suggestions of the parents, so that the teacher receives feedback and shapes his learning goals and practices with children's needs. The proposals made create the conditions for the introduction of an appropriate learning framework and at the same time the encouragement of the participation of coordinators, teachers and parents in young children's learning processes. Introduction and utilization of modern tools in education can bring great gains regarding quality teaching and effectiveness of the adopted practices; however, especially in the early preschool setting the role of well-trained nursery teachers should be supported by all means (Bratitsis and Prappas 2018; Stamatis and Ntouka 2018; Korosidou and Bratitsis 2019a).

6 Conclusion

The literature reviewed shows the benefits of integrating disciplines and implementing combined applications. Therefore, it seems that an interdisciplinary framework in the early childhood education can both have a particularly positive impact on the effectiveness of the learning process and lead to emotional gains on the part of the children. Very young children's active participation was enhanced, while positive attitudes on the part of school advisors, Kindergarten teachers and parents encouraged the implementation of an interdisciplinary approach in the early childhood learning environment. The interdisciplinary learning activities provided opportunities for the development of very young children's communication, digital and physical skills. Interplaying on multimodal interfaces with educational digital tools, as well as interacting in the target language during motion games, role plays and dramatizations was proved to enable children to hone their English oral language skills. The conclusions of this research-synthesis provide with the intention of the Greek Ministry of Education to integrate EFL and ICTs in the official curriculum for Kindergarten, through project-based, interdisciplinary activities. Limitations of the study include the sample size, as a larger sample is required to be considered representative and the results to be generalized or transferred. The feasibility of the early childhood framework proposed should be examined in other contexts in order to identify any further beneficial effects for all stakeholders. Future research is suggested to investigate how interactivity with gameful learning activities can make a difference for very young learners and how they can be intrinsically motivated to play and achieve language learning goals.

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Goodbye Linear Learning: Posthumanism in Dialogue with Indian Communication Theory on Online Education

Machunwangliu Kamei and Sangeeta Bagga-Gupta

1 Introduction

Contemporary scenarios of learning with digital technologies and nexus are characterised by hyper-attention, hyperconnection and hyper-reading with multiple sources of information and knowledge building capabilities which are nonlinear in nature. Instead of viewing knowledge flow as linear, this highlights a scenario wherein the learner's capacity to enter unpredictable networks is encouraged. Kruger (2016, p. 83) refers to this as 'Potentia', an affirmative and creative power which does not take away the power of others to act but instead enables the power of the other 'to expand toward unknown futures' (MacCormack 2012, p. 2). This involves the dynamic movement of knowledge creation that is not limited to one restricted space or an a priori trajectory. Referring to Haraway's (2008) explanation of knowledge in 'Mutations of Thought', Snaza et al. (2014) suggest that:

> knowledge is both highly local, in a particular situation that a body finds itself in, and simultaneously, a gaze from nowhere [. . .] Knowledge seems in these senses to be a result of inserting a bodied perspective into the world in order to generate a system consistent with the position of that body in that world, in other words establishing a dichotomy of domination by that body and non-universal, relative (and hence lacking dominant authority) knowledges (plural) associated with specific positions. (p. 50)

A posthumanism stance suggests that these technologies amplify people's experiences, options and choices in relation to themselves (Herbrechter 2018). Further-

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more, without suggesting that processes of analogue peer learning don't support life beyond the university, nonlinear pedagogies of peer learning in online communities de facto support students for living in lifelong digital spaces (Brown et al. 1994; Donaldson et al. 1996). Pedagogy in online learning environments involves not just the usage of technology to aid instruction but also the theory and practice of enhancing learning interactions engaging the teacher, the learner and the learning environment (Simone 2006; Siraj-Blatchford et al. 2002). The study presented in this chapter analytically examines contemporary virtual sites for learning in addressing issues of access, equity and mobility. It discusses two theoretical perspectives, posthumanism theories and the Indian communication theory of sadharanikaran, which we argue are relevant for illuminating collaborative learning in online networked communities.

Higher education (henceforth HE) is witnessing shifts in student demographics, in that increasing numbers of participants work parallel to pursuing studies. Recent scholarship suggests that since their establishment in 2011, massive open online courses (henceforth MOOCs) have provided flexible opportunities through online education (henceforth OE) platforms and widened access for students (Cinquin et al. 2020; Zhang et al. 2019). Figure 1 illustrates the growth of one such new OE platform, a virtual university.

UoPeople, founded in 2009 and headquartered in Pasadena, California, is the first non-profit, tuition-free, online university in the world (UoPeople 2020). 11,000 professionals currently work as faculty volunteers, and over 20,000 students from more than 200 countries are enrolled at UoPeople. Its official website states that 1000 of its students are refugees, 600 of whom have been displaced from Syria. The Arabic language website of UoPeople (Fig. 2) started operations during the second half of 2020; it will be run by refugees in the MENA region for displaced students. UoPeople uses open educational resources, open-source technologies and business intelligence to optimise efficiency and minimise student costs. UoPeople is the world's first university to build its entire instructional program using open educational resources leading to open educational practices.

MOOCs enable collaborations between HE institutions for providing theoretical and practical knowledge to students in specific fields as well as socially relevant courses not connected to student's expertise areas. The 2020 pandemic crisis has, for instance, pushed many HE institutions to integrate, if not replace, analogue education instruction with OE platform solutions. Figure 3 presents an OE platform FutureLearn's response to the 2020 COVID-19 situation through the creation of tie-ups with health institutes and research centres for one of their courses.

The present study focuses upon OE sites and virtual universities from the perspective of posthumanism and postmodern pedagogy. These sites have been analysed using a grounded theory approach (Glaser and Strauss 1967) which enables an inductive, contextual and processual handling of datasets and helps investigate connections between reoccurring themes (Martin and Turner 1986; Orlikowski and Baroudi 1991). We attend to the following research questions:

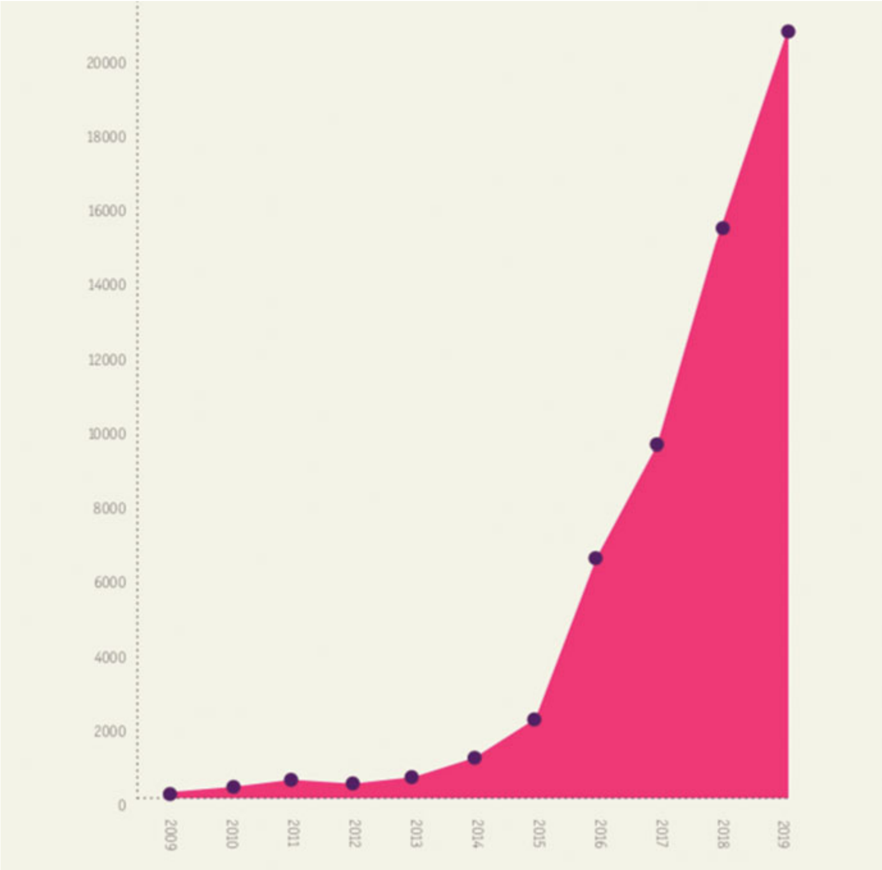

Fig. 1 Student growth rate at an online university – University of the People (UoPeople Annual Report 2019)

1. What are the analytical assumptions embedded in Northern posthumanism theories in relation to a Southern Indian communication theory of sadharanikaran within the context of OE?
2. What do current features of OE sites imply in relation to the types of data that can be relevant for analysing some key spaces of contemporary institutional learning?
3. What issues and challenges exist in contemporary online learning sites, and what types of emerging pedagogical approaches can be identified for OE sites?

Taking these as points of departure, the study attempts to analyse learning models as explicated by different virtual sites. The theoretical perspectives respond to our first question (Sect. 2) and illuminate directions in curriculum design, pedagogical practices and how a nonlinear pedagogy of peer learning in online communities

Fig. 2 UoPeople, an American accredited global online HE's new site in Arabic (UoPeople n.d.)

is conceptualised for preparing learners for lifelong learning through networks (Sect. 5). This, we suggest, is relevant given that the current global learning scenario requires focusing on new approaches of social and sustainable learning models.

2 Theoretical Gaze

We argue here that posthumanism theories and the Indian communication theory of sadharanikaran share key postulates. Both, for instance, emphasise the 'relational' as opposed to the 'individual'. This is relevant for illuminating nonlinear forms of learning spaces which involve navigation through hyperlinks. Drawing from assemblage theory (DeLanda 2016), socio-material learning (Sørensen 2009), actor-network theory (Latour 1996), non-representational theory (Thrift 2008), production of space (Lefebvre et al. 1991), etc., posthumanism approaches decentre humans in the analysis of social phenomena. They call for the application of constructivism which is based on observation and an analytical study of learning given the premise that learners co-construct understandings based on their experiences in both synchronous and asynchronous spaces.

Discussing posthumanism pedagogies in HE, Bayley (2018) calls attention to their innovative, transdisciplinary and participatory dimensions, questioning the humanist focus on humans only in and across time-space. It is in this manner

Fig. 3 FutureLearn COVID-19 collaborative courses (Reproduced from Hopkins 2020)

that knowledge can be seen as nonlinear, constructed through the engagement of both human and non-human entities in networks, rather than by disassociated humans alone; this is envisaged as enabling a democratisation of learning in relation to global interactions (Barad 2007; Murris 2018). Such a stance calls for revisiting concepts like institutional spaces and collective intelligence and involves reimagining intra-generational learning where relational ideas shape knowledge creation (Haynes and Murris 2016; Levy 1999). Bringing actor-network theory to bear upon the production of space, knowledge reconfigurations can be understood within the 'cybernetic triangle of human/animal/machine' (Snaza et al. 2014, p.40).

Ulmer (2017, p. 841) frames such a stance as processual post-inquiries of 'thinking without, thinking with, and thinking differently'. Cook (2016), in similar light, highlights a 'four corners approach' regarding affinity space members:

> Pedagogy in affinity spaces is peculiar. It seems impossible to pinpoint precisely where education occurs in these contexts. The learner is taught alternatingly by peers (with an emphasis on the plural), herself, her tools, her environment and the task, making this a distributed pedagogy. (p.79)

Turning attention to the Indian communication theory of sadharanikaran, which is derived from Bharat Muni's 'Natyashastra', Kapadia-Kundu (2015) explains it as 'simplification without dilution' representing:

> a communication tradition that includes simplification, rasa (emotion), sahridaya (compassion with affection), asymmetry (hierarchy) and social universalization. Sadharanikaran explicates the relational and social processes of communication. (p. 1)

Here communication in a learning community finds its reference in Gurukul, the ancient Indian system of education. The student in Gurukul lived together as an equitable member of the guru's family, facilitating knowledge acquisition by being/living in the learning environment. The arrangement was dialogic in nature wherein students learned from daily interactions and being in the guru's presence. Learners assisted their teachers in the learning process and helped build the learning environment. In other words, Gurukuls would not exist if learners were not part of the learning environment.

Gurukul systems inspire understanding online spaces where learning takes place in a similar fashion. A 'posthumanism guru' need not always be the designated course instructor, but could be a peer, the machine, AI or the learning environment itself. Learning therefore here is nonlinear, asymmetrical and unpredictable. In Ranciere's (1991) words, there is no major differentiation between teachers and students; both are interdependent, and role reversals transpire continuously depending on the context. Sadharanikaran in a Gurukul system constitutes a manifestation of intrapersonal communication through self-realisation which then enhances interpersonal communication in the learning meshwork. Sadharanikaran pedagogy builds on the premise that knowledge construction needs a common ground of understanding and recognises that asymmetrical learning takes place in networks.

A sadharanikaran approach thus attempts to identify the common ground/commonality through *Dhvani*, i.e. meaning formation for establishing *Vidyā*, i.e. knowledge through mutual processes of sharing and propagation. This is based on the Rasa principle of *ekakabhāva*, i.e. singular emotional experience and empathy, to achieve commonality. Choudhary and Bhattacharya (2014) highlight that *rasa* – the emotional state of understanding – needs to be experienced by participant communicators if relevant meaning-making processes of messages, where *bhāvas* (expression) are deployed, can be accomplished. The participating communicators are, in such a framework, required to experience similar kinds of *rasa* to acquire collective oneness and commonality leading to *ekakabhāva* and collaboration in meaning-making. Rasa theory is relevant to multimodal communication learning theories as both highlight communication that occurs at different levels rather than in a linear manner.

As highlighted above, a sadharanikaran approach also emphasises self-realisation and self-fulfilment, and this is seen as contributing to *Atma-jnana* (self-knowledge). The goal of this process is *Advaita Vedanta* where *Advaita* implies the non-duality of equality. *Vedanta*, also known as Mayavāda, is a school of Hindu philosophy, which advocates achieving emancipation through self-realisation, a process of acquiring

Fig. 4 Posthumanism and sadharanikaran key themes

knowledge of one's 'true' identity. The posthumanism concept of universalism thereby overlaps with the idea of *Brahman*, the formless, asymmetrical in-progress, nonlinear foundation of *commonality of all* that exists. Discussing a posthumanism tenet, Bateson (1972) highlights that each person is a node providing a central metaphor through which we become conscious of the world.

Sadharanikaran emphasises collective, relational and emotional aspects of communication (Kapadia-Kundu 2015). For instance, Yadava (1987) discusses sadharanikaran's five tenets of compassion, emotional response, asymmetry involving unequal communication, simplification without dilution and universalisation which involves a collective response. This concept of universalisation is similar to Barad's (2007) stance on matter and discourse as a mode of performative posthumanism. Both focus on connectivity and relationality, where everything and everyone continues to remain in continuous exchange in communication processes.

In response to the first objective of the study, Fig. 4 summarises this section, highlighting and bringing together key tenets of posthumanism and sadharanikaran philosophies. This further leads to complementary themes which include self-realisation, autonomy, critical learning, decentering, collaboration, constructivism, asymmetrical learning, relativism and universalism. The next section describes the data that we engage with in the present study.

3 On Data and Methodology

We use self-ethnography and non-participant online ethnography by applying what we have explicated as a ‘turn-on-turn reflexive’ mobile gaze related to ‘Where, What and When Is the Data’ in virtual spaces. Thus:

> What (n)ethnography affords educational research today (focusing on human meaning-making) is the ability to map individuals’ digital contributions to locate the movement of information and ideas across time and space. We argue that such a stance is key if we are to contribute from an emic, that is, participants’ perspective. Such possibilities enable the creation of datasets that can be very large, encompassing a wide range of spaces and activities. (Bagga-Gupta et al. 2019, p. 371)

Scrutiny of pedagogical models of five popular MOOCs – Coursera, edX, XuetangX, Udacity and FutureLearn – is used together with the study of UoPeople, introduced earlier, to illuminate the basic assumptions that underlie the wider context of open/distance learning. This further helps in examining how contemporary spaces of HE address issues related to access, equity and mobility through the prism of their institutional policies. Our positions as instructors and learners in some of these sites afford a reflexive stance. Five MOOCs were selected on the basis of popularity and a rise in student enrolment as reported by earlier studies and the Class Central MOOC Report 2018 (Li 2017; Liyanagunawardena et al. 2019; Shah 2018) (Fig. 5).

UoPeople was further chosen for a detailed case study because of its unique features (Sect. 1). Data was generated between January 2019 and May 2020 and consists of the following:

- Official policy materials of the five MOOCs and UoPeople available through their websites and different social media (Twitter and Facebook) posts.
- Online group discussions in asynchronous modes on various platforms. Such types of forums have been reported to be observable, effective and accessible and limit the pressure of participation and time (Anderson and Kanuka 2006).
- Students and MOOC course support forums/groups in social media platforms (where the researcher participated as an online ethnographer; discussions were

Fig. 5 MOOC provider and number of users (Adapted from Class Central Report 2018: Shah 2018)

MOOCs Provider	Number of Users
Coursera	37 million
edX	18 million
XuetangX	14 million
Udacity	10 million
FutureLearn	8.7 million

Response thread	Codes
Teacher evaluation only indicates to students the areas that want enchancment however self- and peer assessment doubtlessly have interaction students in the thinking manner itself as they strive to understand, analyse, clarify, remark and defend each others' work in order to enhance it. When assessing, college students decide the extent to which their personal or their peers' work has met the criteria. They need to find evidence from the textual content to justify the grading made. In fact, they analyze to give positive feedback to their peers. The extra possibility they get to practise these things to do the higher their contrast and judgment competencies are enhanced. Self reflection is a very big part of assessing my peers assignments. All the feedback i've received so far has been really good. I just hope I can continue to give valid feedback to my peers.	**peer learning**
When I receive feedback from a peer it pushes me to critically think about why they responded the way they did. It makes me reflect on ideas that I may have missed and makes me think of additional things I could have added to make my work better. Collaborative learning has many benefits for the student. It allows the student to have a greater understanding of the material being taught, through peer-reviewed assignments and discussion assignments.	**collaboration and critical thinking**
Active learning can also use collaboration with mentors and/or peers to discuss and ask questions about the work being studied. This can be far more beneficial than a lecture where there is little or no interaction with the teacher and you just receive the information. All this helps students gain a deeper understanding of the material.	**community support**
One who takes charge of their learning process and takes the initiative to learn is a self-directed learner. Self-driven learners don't wait to be guided by others-rather they understand that they decide what, how, and when to learn. Consistently, self-directed learners pursue the ability to improve themselves by learning and are fundamentally inspired to learn.	**autonomy**

Fig. 6 Sample coding of responses in discussion thread

initiated in some of these forums to generate students' opinion on their online learning experiences).
- Student testimonials provided to UoPeople and student testimonials in the social media sites of some MOOC courses (Fig. 6).

The coding process involved identifying datasets which could be categorised under codes in relation to collaboration, autonomy, peer learning, community and technological support, etc. Analysis builds on the premises of grounded theory and has involved coding the data, customising the code system, category building and constructing theories. Codes and memos from the data were organised by using MAXQDA qualitative data analysis software. Figure 7 illustrates the initial arrangement of data and open coding that involved document segments based on the above datasets. These segments were again reassessed through creative coding and memoing.

Some of our previous research on boundary framings across physical-virtual spaces (for instance, Bagga-Gupta et al. 2019) has focused partly on datasets that emerge from student's participation in higher educational settings. There we highlight the researchers' reflexivity positioned as both instructor and learner – 'being *there*, but at the same time also *here*' (ibid., p. 365) – as being relevant to these types of mappings. Multiple mappings and coding techniques on the datasets have given rise to recurring themes that were further mapped on to the main complimentary tenets of posthumanism and sadharanikaran theories (Fig. 4). The next section presents these analytical themes that characterise contemporary OE and the nature of datasets that are relevant for studying OE.

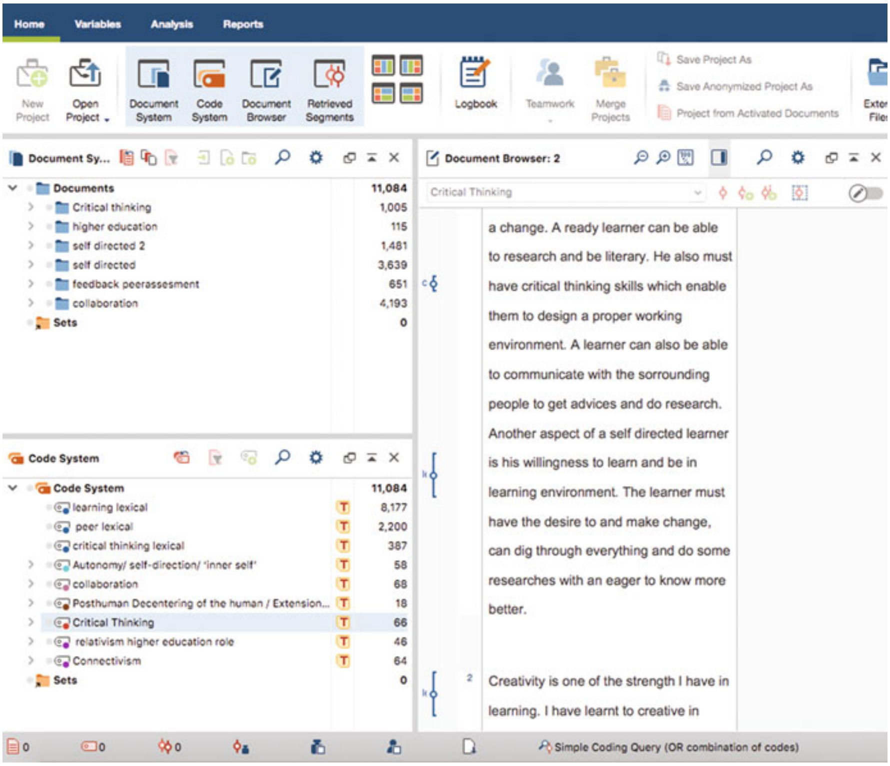

Fig. 7 Screenshot of initial data and open coding in MAXQDA

4 Features, Issues and Challenges of Contemporary OE Platforms

cMOOC and xMOOC constitute the two major types of MOOCs in existence. While cMOOC is seen as building on the principles of connectivist philosophy, xMOOC builds on traditional behaviourist models (Downes 2013). Udacity, Coursera, edX, XuetangX and FutureLearn fall into the xMOOC category. However, recent developments, as observed through this study, indicate that a connectivist pedagogy is being integrated in xMOOC courses too.

The following four main thematic clusters have emerged in the analysis, of which the first three overlap and are for heuristic purposes differentiated here:

- Collaboration
- Community and technological support
- Learning
- On studying contemporary OE spaces – identifying datasets

While the first three constitute analytical themes, the fourth draws on the first three to identify datasets relevant for studying OE learning environments. These have the long-term potential of supporting/streamlining instructional and pedagogical designs.

4.1 Collaboration

Our analysis of the OE cases point highlights ‘community’ in learning. Two subthemes where collaboration is a key dimension are discussed here.

4.1.1 Collaboration, Learning and Assessment Within Courses

An important characteristic of OE courses is that students are required to collaborate and share knowledge in discussion forums, through group assignments and projects. This includes engaging in peer evaluation and review processes.

This can be illustrated by how engineers in FutureLearn use their internal development blog to write about complex codes using self-reflecting concepts, reconceptualising them in their writings and thereby helping others learn in the process (Fig. 8). The major onus of learning is on the students who share their experiences and contribute new ideas for the benefit of all participants. Their progress is then assessed by course mentors who are tasked with providing relevant feedback and guidance. While some OE course projects are evaluated by students based on peer grading rubrics, in others evaluation is carried out by the instructor or is automated. Coursera has calibrated peer review (henceforth CPR) assessment, which can be used for open-response assignments, such as essays. CPR requires that every time students submit an assignment, they – based on teacher-defined rubrics – review and give feedback to some other students (Coursera n.d.).

Students in these OE courses highlight that online collaborative work supports cooperation, productivity and compassion. They feel that a collaborative learning method adds to higher thinking skills and group and conflict management. Social skills are understood as being enhanced through teamwork and cooperation when students receive peer criticism. Peer grading, according to the students, enables them to improve their understandings of subject content in the course as they gauge where the rest of the group stands, enhancing their own level of involvement.

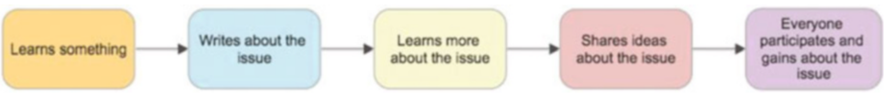

Fig. 8 Different ways engineers learn from each other at FutureLearn (Adapted from FutureLearn 2020)

Community-oriented or collaborative learning is thus seen as promoting knowledge management skills when students are exposed to ideas from different sources and for generating multiple solutions to a problem. It was also observed that the connectivity pedagogical model in OE courses extended to informal and formal learning communities with the use of social media platforms (see also Sect. 4.2.1). A connectivism approach and connective knowledge developed through interdependent networks can therefore be understood as being pluralistic (Downes 2013).

4.1.2 Industry and Academic Collaborations

Another feature of OE platforms relates to their collaborations with industry and scholarship. An instance of this is FutureLearn that is a consortium of 12 major UK universities. Similarly, in the case of edX, two edX partner institutions can work across different time zones, languages, cultures and academic calendars to produce a learning experience in a program that is offered jointly. A key component related to this development was the establishment of 'MOOC residencies' which allowed team members to be together for short periods. XuetangX's popularity is related to its MOOC + learning model that includes three major online features: tie-ups with academia (MOOC + university certification), skills-based courses (MOOC + certification of practical training) and value-added courses (MOOC + enterprise certification and MOOC + degree certification). XuetangX's course MOOC + certification of practical training model is an online algorithm training camp which involves community group-based projects and practical exercises that provide flexibility for learners (XuetangX: Online courses from top universities n.d.). Figure 9 illustrates this theme through XuetangX tie-ups with the Sustainable Development Goals (SDG) Academy that provides courses on sustainable development as part of United Nations initiatives.

As was highlighted in Sect. 1, UoPeople too builds on academic and professionals' collaborations. Its leadership comprises, for instance, of academics from Columbia, Harvard, Stanford, Oxford, NYU, UC Berkeley, Georgetown University, etc.

4.2 Community and Technological Support

Support by communities and technologies has been identified as a second theme that is a hallmark of contemporary OE platforms. In addition to OE platforms being conceptualised as communities (see Subsection 4.1), the nature of support that is extended is complex: support through official and non-official ways and virtual and physical networks. This theme is elaborated through three subthemes of digital and physical support structures in place and the role of general technology and AI in these spaces.

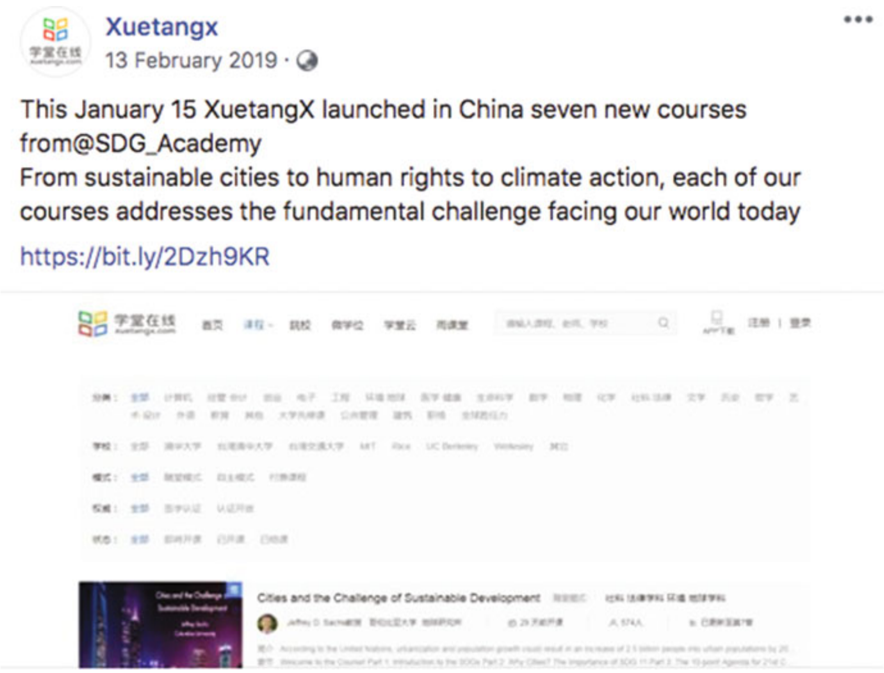

Fig. 9 XuetangX new courses based on sustainable development goals (Reproduced from XuetangX Facebook page 2019)

4.2.1 Social Media and Networking

Many MOOC courses have informal and formal course groups that have the explicit aim of enabling peer support, creating socialising arenas, networking and supporting motivation. Popular platforms like Facebook, Instagram, Twitter, Quora, WhatsApp, etc. are commonly used for informal networking. Some courses have their own networking facility integrated in their platforms. Figure 10 illustrates such a chat facility – Student Hub – that is integrated into Udacity's platform (and as a mobile application) for peer support. This is accessible for members including alumni and current students.

This support from students and multiple mentors is accessible for members 24/7. Furthermore, peer support extends in many informal networks. Figure 11 illustrates how community support among OE learners from different platforms extends across informal groups through the affordances of social media. In addition to such support features, references and course ratings by alumni also add to course popularity and influence student enrolments.

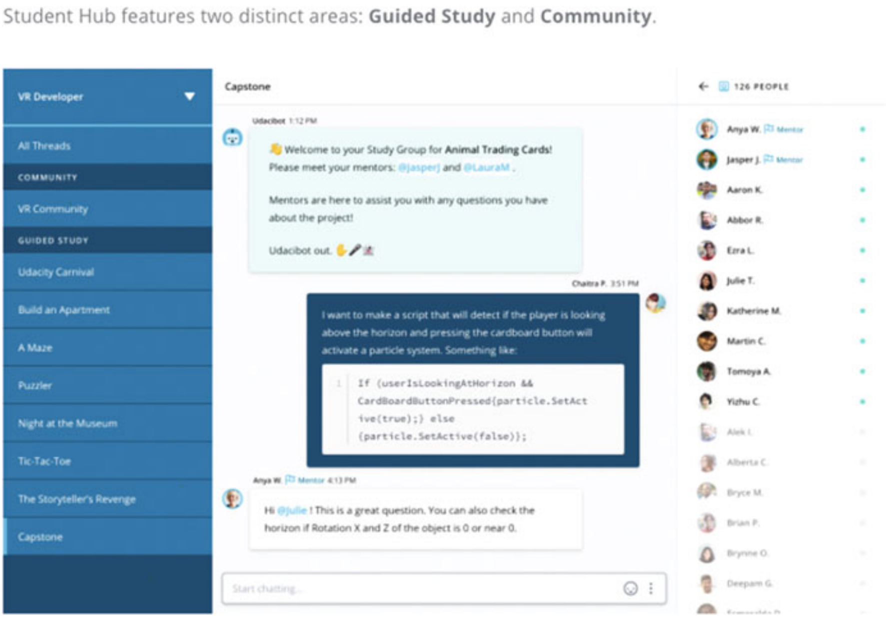

Fig. 10 Student hub features of Udacity (Steurer 2019)

4.2.2 Community Support in Physical Spaces

Another feature of OE platforms is the analogue support that many provide and which highlights their porous nature. Coursera, for instance, is currently experimenting with in-person learning groups to supplement its online learning program. edX also follows 'blended' learning designs in some of its courses with both online and face-to-face meetings. Another example of this feature is the Udacity Meetup community where students can check course forums, study group tags and visit their city's meeting site, identify what community events are coming up in their area, etc. This feature connects student communities with mentors who can directly address student feedback. Mentors attached to study group projects also act as project reviewers. Classmates who are working on or have completed their projects are also active in these groups (Udacity n.d.). Udacity reports twice as much student participation in this mentorship approach (as compared to their regular courses). Figure 12 illustrates the growth of Coursera Meetup communities since 2012 where students provided course support in person (Press 2012).

FutureLearn too makes available physical spaces where students have the option to join a study group with 80 members. Study groups are used as spaces where weekly themes/topics can be discussed. FutureLearn encourages group learning where course mentors are occasionally present. Meetup.com is its initiative where students in different geographical areas form 'communities' that host 'meetups' whose details are presented in their FutureLearn Meetup page. Students can start

Fig. 11 Learners sharing experiences with peers in social media sites (Reproduced from MOOC Facebook group 2020)

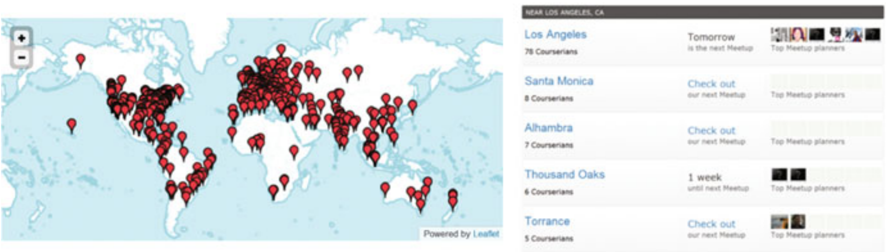

Fig. 12 Coursera meetup cities and Coursera meetups in Los Angeles (Reproduced from Press 2012)

a new community if their areas are not listed in the Meetup page. The learning model in FutureLearn engages with collaborative learning where such study groups are understood as being supportive of the participants research and group project work.

4.2.3 Use of General and AI Technology

Technology used in the OE platforms is either open source or proprietary which shapes the Learning Management System, Course Management System and Learning Content Management Systems. The types of course content and modes of course delivery appear to play key roles for providing access to learning. Contemporary OE platform courses include usage of reading materials, audio-video learning and instructional materials with activities like intermittent quizzes and games that test learner's understandings and engagement. Micro-videos, downloadable learning materials and external links are also used.

In addition to community and technological support that contemporary OE platforms provide in both digital and physical spaces (see Sects. 4.2.1 and 4.2.2), an important characteristic is the use of AI technology in these platforms. XuetangX, for instance, uses an AI virtual teacher called Xiaomu which serves as a personal mentor for each enrolled student. Xiaomu actively monitors each student's engagement in the course by asking questions related to what is being covered in a course, for instance, through texts, pictures, videos, etc. With the help of user's algorithms, Xiaomu further recommends relevant courses to help student's future trajectories at the end of a course. Another example is a student verification process in Coursera that involves a signature track. Based on the student's typing style, a keystroke signature is created. This data is processed by a neural algorithm which determines a biometric template of the user's typing pattern used for future authentication. Figure 13 represents edX's personalisation provision built up with learner-centric software.

Researchers at UC Berkeley are reported to have further enhanced the edX platform by applying machine learning recommendation algorithms for identifying learning materials/pages which the learners would find more engaging. edX has approximately 54 assessment and learning tools, and these include virtual proctoring, peer grading, self-grading, machine grading, and staff grading for assessments. Collaboration with the University of British Columbia is reported to have introduced a Peer Instruction Tool in the edX platform. This tool adds peer learning pedagogy in a virtual learning model by supporting learner's collaboration in group assignments, for assessing one another's work and resubmitting responses. Such features are seen as scaffolding learners' experiences. edX has a new unique automated essay scoring (AES) device which trains itself to grade essays using machine learning algorithms based on how a human grader manually evaluates the first hundred essays. AES systems build statistical models by tracking specific patterns and characteristics of human grading. They are considered capable of using complex computational elements from the field of Natural Language Processing (NLP), such as automatic summarisation, discourse analysis or sentiment analysis (EdX courses, edX n.d.). Their advantage lies in their prompt provision of qualitative and quantitative feedback to students. The platform holds another advantage regarding multimedia in that some courses feature lab sections with interactive embedded applications.

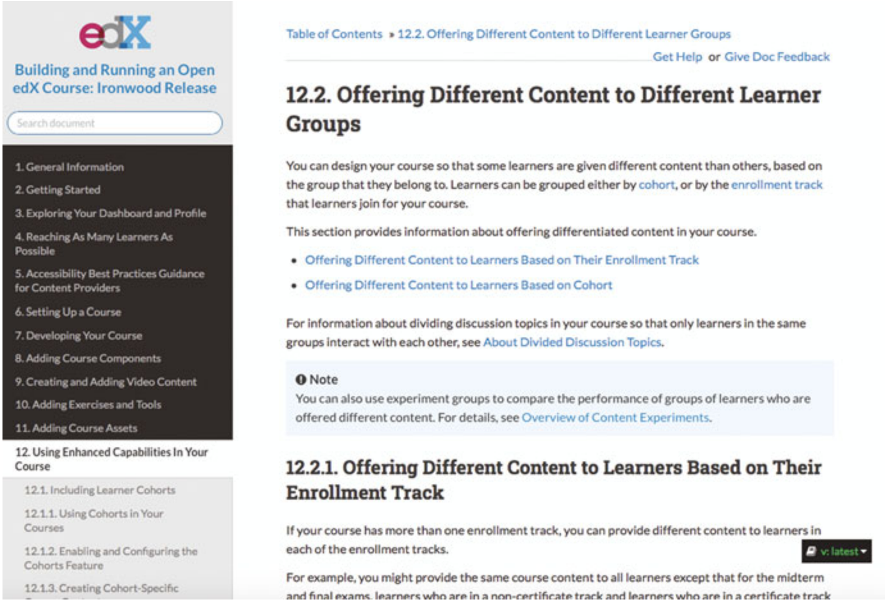

Fig. 13 edX offerings of content personalisation for learners (edX n.d.)

4.3 *Learning*

The first two analytical themes presented above build on the premise that OE platforms are institutional learning sites. Specific subthemes related to learning are presented in this third theme. The first two deal with the role of HE in relation to online learning broadly and specific issues and challenges of online learning. The third subtheme focuses on critical thinking and autonomy, two complimentary tenets of posthumanism and sadharanikaran theories.

4.3.1 HE and Student Profiles in Online Learning

The political, economic and social milieu in which students are positioned has important implications for the current role of HE. This section discusses students' opinions based on their responses (see Sect. 3). Students stress the need of HE for partnership between government, industry and institutions. HE is seen as playing a key role in guiding students in appropriate selection of specialisations and in preparing them for challenges and issues related to technology and demands of current and future labour markets. Students specify the importance of mobility provided by online learning given that they can be members of more than one university through credit transfer systems. They view digital learning landscapes, popular in contemporary self-paced learning, as advantageous for saving time, providing

Fig. 14 UoPeople student testimonial (Reproduced from UoPeople Facebook page 2020)

quality information and convenience, enhancing collaborations and enabling faster acquisition of skills. HE is viewed as playing an important role for addressing issues related to accessibility, gender equity, socio-economic status, age, environment and flexibility, for being intellectually challenging and for preparing students to be contributors to society. Figure 14 illustrates a UoPeople student testimonial on how online learning has enabled her to continue with HE.

Student profiles in many of these courses are heterogeneous with international, mixed -age group participants and adult learners or from regular colleges, from unemployed or employed and from different socio-economic backgrounds. Motivational factors for participating in OE platform courses include skill enhancement, career advancement, better employability or as part of university add-on courses with credits or to attain a further degree/diploma/certification. Course duration ranges from 4 to 9 weeks or more, and these are either self-paced or of a fixed duration. Students sometimes have the option to reset their course completion timelines, adding to flexibility and a push to continue HE studies.

Students also find the personalisation provided by some of these environments helpful in adding to their learning experiences. Participants emphasise the need for OE platforms to further empower students to build their own learning and knowledge environments. Priorities regarding what one wants to study for one's professional development play a key role in how individual's plan for and gain autonomy in learning. Online learning with institutional and multiple collaborations, as discussed above, enables students to potentially become independent.

4.3.2 Issues and Challenges of Online Learning

In monolingual OE platforms, students with multiple language backgrounds face a complex learning situation. Multilingual students who are familiar with English sometimes face issues when expressing themselves in *only* English environments compared with students whose primary language is English. This is seen as shaping online collaboration dynamics and also peer grading and evaluation because of a lack of clarity in expression. Recent developments at UoPeople, where its Arabic language portal launched during the second half of 2020, constitute one way through which the hegemonies of only English provision in OE platforms are being addressed. Another similar initiative is XuetangX which operates edX courses and is the world's first Chinese MOOC platform. The need for 'intercultural' communication skills in online networking requires time to adjust to heterogeneous group settings. Students also require navigation and time management skills for managing information in online spaces.

OE platforms involving peer grading require that students learn peer evaluation and peer grading rubrics. Despite being aware of peer evaluation benefits, some students expressed concerns about not being assessed properly. Plagiarism in assignments and projects are other challenges highlighted by students. Netiquette in the learning environment is another issue that affects peer learning dynamics. As alluded in 4.1.1, the motivation to continue learning online is a challenge which students encounter when interactivity and engagement levels within courses drop.

Course designs (for instance, synchronous instruction) that rely on fast internet speed and bandwidth constitute a major roadblock for students in remote regions from continuing with online learning. Having synchronous and/or asynchronous delivery of content is an important decisive factor: synchronous modes at times enhance active participation, and asynchronous modes of delivery address issues of mobility and flexibility of learning along with data usage issues. Similarly, providing learning systems that are web-based would require students to be connected online. On the other hand, computer-based learning allows students to continue learning even when internet access is limited. As our fourth theme illustrates below, the types of challenges raised here need further attention for addressing issues of design and accessibility of current OE platforms.

4.3.3 Critical Thinking and Autonomy in Learning

Online learning pedagogies share principles related to posthumanism and sadharanikaran. For instance, autonomy in learning calls for self-realisation, taking ownership and knowledge management on the part of students. Autonomy in learning involves student's navigation and assimilation of the course and not just a teacher's explication of the syllabus. Thus, students are not merely dependent on teachers but are required to take ownership of their own learning. Figure 15 highlights the interrelationships between autonomy and collaboration where codes (indicated in blue) under autonomy, knowledge management and self-direction skills display co-occurrence in subcodes under connectivism and collaboration (indicated in pink).

The codes are based on students' responses in discussion forums (see Sect. 3) where questions were administered on autonomy in learning and the role of collaboration. In their responses, students highlight that learning is a process that is initiated when an individual decides to plan his/her own way of understanding something; at this point, the students' skills and knowledge enable self-sufficient planning of their own learning pathway, illustrating that they are motivated, self-focused and involved in learning. The interlacing lines indicate the level of code

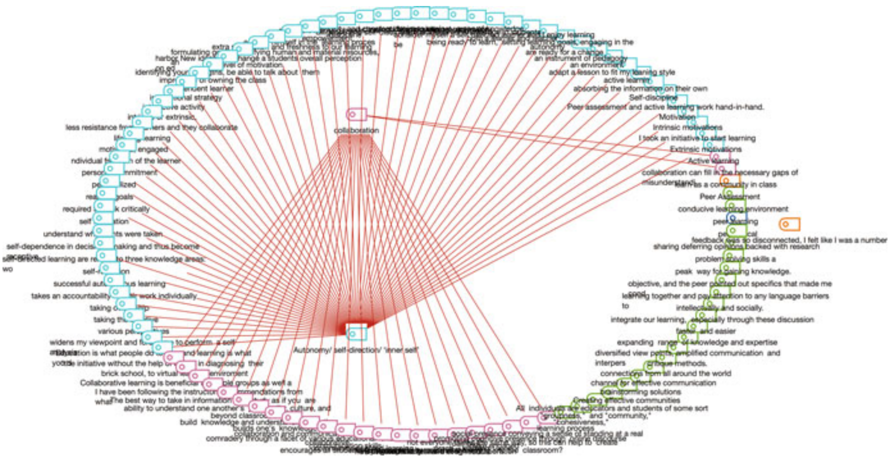

Fig. 15 Code co-occurrence between autonomy and collaboration

co-occurrence, i.e. similar codes appear under autonomy and collaboration. Students in our datasets highlight that autonomy in learning involves agency/ownership for creating independence and responsibility, both of which are seen as essential requirements for intrinsic motivation and successful learning. Intrinsic motivation through self-realisation leads to the creation of a positive and proactive learning environment wherein students can make sense of information and understand their limitations and what directions to take in order to keep track of their own progress. The code co-occurrence level in Fig. 15 shows students' responses that point to the need for autonomy in learning skills for becoming better collaborators in the learning network.

As explicated in Sect. 4.1, collaboration has emerged as a key feature of OE platforms. Learning processes, students feel, are enhanced by supporting the development of their skills to critically analyse information, engage in giving constructive feedback and assess information in a collegial and encouraging manner. Challenging interpretations through others' contributions in discussion forums leads to continuous self-improvement, active learning and critical thinking, they highlight. Coding the data, customising the code system and category building using MAXQDA software (Figs. 6 and 7, Sect. 3) highlight interrelationships between collaboration and critical thinking (Fig. 16). Initial open coding of discussions with students under code themes of peer learning and community support was further compared and categorised as part of the methodological approach of looking at the data multiple times.

Figure 16 illustrates students' responses wherein the relationship between collaboration and promotion of critical thinking abilities is strong. Responses from the students in the discussion threads (see Sect. 3) further substantiated our earlier discussion that posthumanism education which involves digital navigation necessitates critical thinking in these communication spaces. Collaborating students

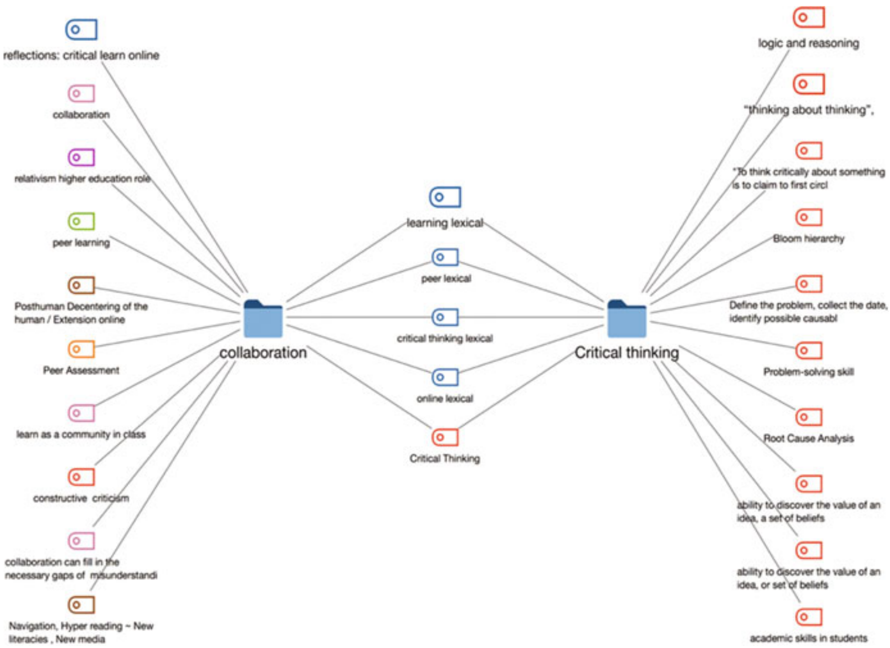

Fig. 16 Two-case model between collaboration and critical thinking

highlight that discussions play a central role for their analysis of course materials. Discussions allow for thinking critically by looking beyond what is presented, locating gaps in the information by asking questions and analysing and evaluating what has been covered in the courses.

The three themes discussed so far spell out the features, issues and challenges of contemporary OE platforms. Building on this analysis, our final theme draws attention to how these features hold the long-term potential for streamlining of instructional and pedagogical designs.

4.4 On Studying Contemporary OE Spaces: Identifying Datasets

In response to the second objective of this study, contemporary OE features spelled out under the first three themes along with the summarising features presented in Fig. 17 point at overarching datasets that hold promise for the analysis of virtual sites for learning.

The overlapping themes of community and technological support in and through OE point to technology and course management systems used in these platforms as future areas of study. The decision of choosing open source or proprietary systems

Fig. 17 Contemporary OE platform features and future areas of investigation

leads, for instance, to a study of policy initiatives. This in turn shapes the learning environment created by the technical (yet human) aspect of Learning Management Systems, Content Management Systems and Learning Content Management Systems. Learning systems can be either synchronous or asynchronous, and their nature determines the flexibility and access provided by OE. Synchronous or asynchronous modes that are deployed engage the students while keeping the internet data usage in mind together with communication and feedback mechanisms that influence the level of interactivity and student engagement.

Understanding how peer learning and collaboration takes place along with an evaluation mechanism (instructor-oriented, peer-oriented, automated or a combination of these) constitutes areas of data sources. Learning analytics along with student backgrounds based on their demographic profiles provides understandings of their motivation and learning curves. Course structure and duration are also sources of data for analysing how these shape students' course involvement and completion. Data analysis emerging from references, ratings, course costs and certification also has the potential to illuminate their influence on course enrolments.

The analysis of these features, illustrated in Fig. 17, identified from contemporary OE platforms can offer support for developing instructional and pedagogical designs that can scaffold student's learning environments and learning conditions. The

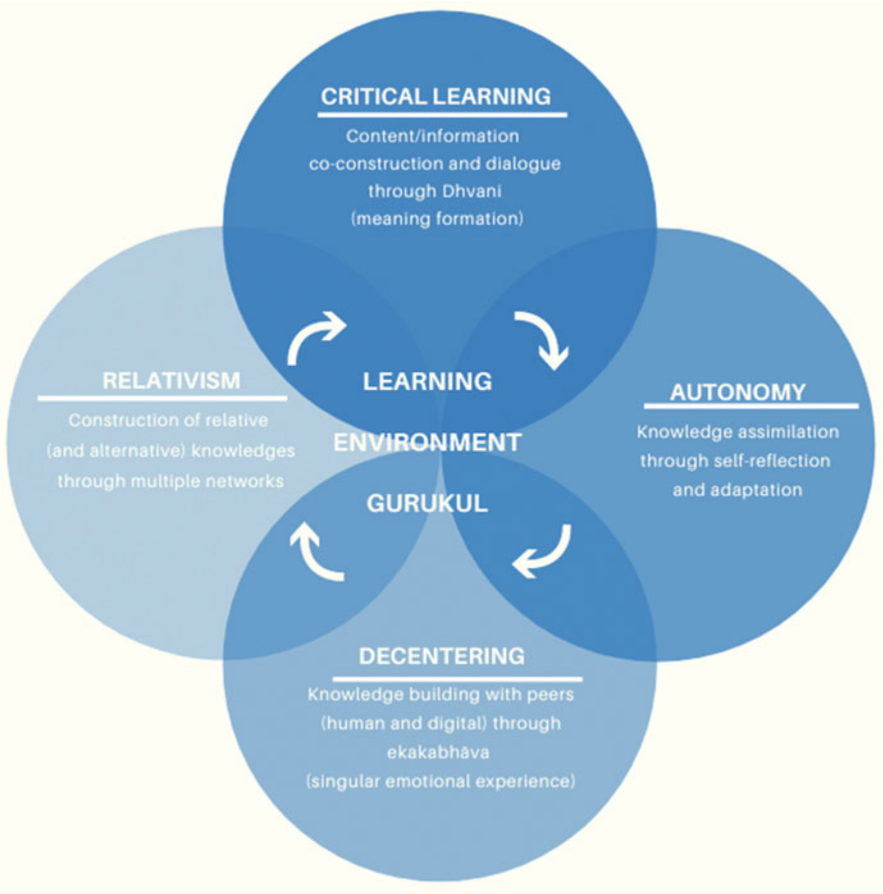

Fig. 18 OE pedagogy based on posthumanism and sadharanikaran tenets

decentering of humans thus involves the extension and mobility provided by technology through OE platforms. As identified through this study, each human and non-human data source can be critically re-examined for emerging pedagogical and instructional approaches. The features that have emerged and that have been highlighted here constitute nonlinear networks that exist in OE platforms. Figure 17 highlights key themes that future researchers can study applying the suggested OE pedagogy based on posthumanism and sadharanikaran tenets as outlined in Fig. 18. The final section links our findings and contributes to emerging pedagogies based on posthumanism and sadharanikaran tenets.

5 Going Beyond Linear Learning

Tenets of posthumanism and sadharanikaran theories discussed in Sect. 2 and the analytical themes discussed in Sect. 4 draw attention to dimensions of online pedagogy which can engage participants in specific ways. A significant challenge in online spaces relates to shifting and alternative epistemologies, which call for relooking at the changing positionalities of students and teachers. Both posthumanism and sadharanikaran approaches call for this relativity and shift in the meaning-making process. As Downes (2013) highlights, in cMOOC environments, all participants are both teachers and students. Drawing on posthumanism, Murris (2018) points to the impermanence of having a diffractive teacher where collective knowledge and the notion of relativism further lead to virtual learning environments wherein each participant forms a node in learning networks.

Cook (2016) further adds to posthumanism perspectives wherein 'pedagogy is distributed among individuals, structures, objects and others. It is to some extent self-organising and maintaining, and is therefore not simply created and used by a single teacher' (p. 166). This is akin to a posthumanism guru in a virtual Gurukul which builds on non-dualistic, nonlinear pedagogical approaches (Fig. 18).

Based on the tenets of posthumanism and sadharanikaran theories (Sect. 2, Fig. 4) and the analysis of the datasets presented in Sect. 4 and in particular the features of contemporary OE (Fig. 17), we suggest a posthumanism sadharanikaran pedagogy (Fig. 18) which builds on a Gurukul learning environment model. This involves:

- Content/information co-construction and dialogue through *Dhvani* (meaning formation)
- Knowledge assimilation through self-reflection and adaptation
- Construction of relative (and alternative) knowledge through multiple networks
- Knowledge building with peers (human and digital) through *ekakabhāva* (singular emotional experience)

Participants in these processes are understood as being in constant, interchangeable dynamic positioning of knowledge exchange and construction. The role of the learning environment, i.e. the Gurukul, becomes important here where human/non-human actors engage in peer learning processes. Motivation for learning in such a Gurukul model begins with self-realisation which extends to nonlinear co-constructed peer learning spaces. Learning takes place through 'simplification without dilution' based on the rasa concept of singular emotional experiences for achieving commonality. Such knowledge construction further circulates among peers through relational ideas that shape nonlinear knowledge creation. This constitutes ongoing knowledge construction processes in learning networks.

Sadharanikaran in online communication sites involves understanding relational processes of learning vis-a-vis individual constructs; it places collectivity as a central response to learning and for addressing some of the challenges faced in contemporary OE platforms. Posthumanism approaches confirm student experiences, illustrated in this study in terms of multilayered, multi-connected educational landscapes. This is relevant for preparing students for lifelong learning through networks given that contemporary global learning scenarios call for focusing on new approaches of social, solidarity and sustainable learning models. Learning in such contexts is relational, capacitating students to construct their own knowledge spheres. Thus, posthumanism sadharanikaran pedagogical practices have the potential to create and sustain online learning communities as models which incorporate collaboration across their multiple layers.

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Users' Preferences for Pedagogical e-Content: A Utility/Usability Survey on the Greek Illustrated Science Dictionary for School

Ioannis Lefkos and Maria Mitsiaki

1 Introduction

Web-based education has been around for quite some time but gained much attention and massive participation worldwide during the last 10 years (Kidd 2010). Several months ago, the coronavirus lockdown gave even more impetus to e-learning practices and contents for younger learners either in the first (L1) or in the second/foreign language (L2), testing, thus, their efficacy and readiness. At the same time, numerous scholars and educators stress the urgent need to handle an avalanche of new digital skills embedded to a handful of new literacies (a.o. Cope and Kalantzis 2000; Luzón et al. 2010; Henderson and Romeo 2015), so that distance education and e-learning practices are not fragmentary but holistic (Tzifopoulos 2020; Williamson et al. 2020), leading to learning approaches "not about the computer" but "with the computer" (Koutsogiannis 2011).

Such multiliteracies are characterized by (a) *embeddedness*, since they are embodied into different discourses/texts, and (b) *interconnectedness*, since several combined literacy types are required for the redefined twenty-first-century competences. The embedded learning perspective shifts the emphasis from the "narrow in-the-mind" vision to "a broader person-in-the-world" vision (Chee 2007: 14), whereas the interconnected perspective attempts to get the most out of the newly emerging web genres, allowing for more interdisciplinary practices.

Scientific literacy, as viewed in the recent study of the Committee on Culture and Education (Siarova et al. 2019), can be considered to be such a "literacy cluster"

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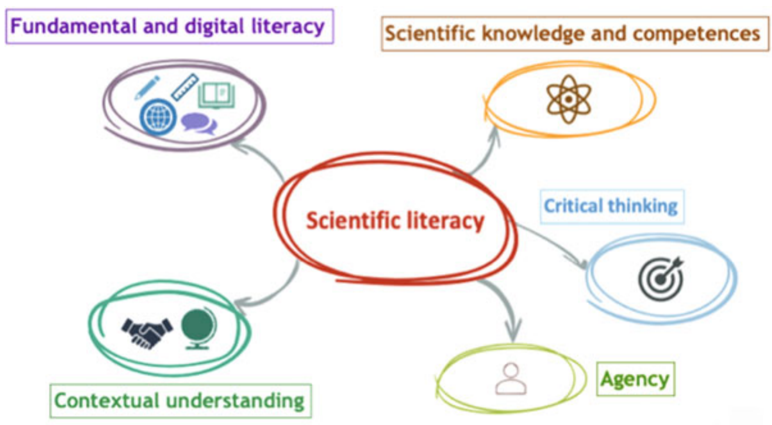

Fig. 1 Key components of scientific literacy (Adapted from Siarova et al. 2019)

embodying several competences, skills, and literacies (Fig. 1). The expanded notion of scientific literacy serves three visions: *Vision I* places the emphasis *within Science*, *Vision II* views *Science in relation to society*, and *Vision III* involves learners *in Science within society* (Liu 2013: 29).

Simply put, scientific literacy calls for:

- *Basic* reading, writing, listening, speaking, math *skills*
- *Digital skills*, such as getting involved in critical learning offered via e-tools, in a way that learners master ideas and not keystrokes (Gilster 1997)
- *Hands-on skills* (experimentation)
- *Critical information skills*, such as inquiry, analysis, synthesis, report, explanation, and argumentation (Osborne 2002)
- *Core scientific skills*, such as understanding the language and content of Science (Wellington and Osborne 2001)
- *Cultural skills*, such as contextualizing scientific concepts and phenomena (Plakitsi 2010)
- *Civic literacy skills*, such as public understanding of Science for active citizenship (Miller and Pardo 2000)
- *Media literacy skills*, such as being able to assess the meaning of any kind of messages connected to the public understanding of Science and conveyed through media (Potter 2001; Hobbs 2011)

Under such a dynamic perspective, e-Contents are expected to keep pace with a more grounded approach; they have to be flexible, multifunctional, and tailored to the complex needs of the twenty-first-century netizens, providing, thus, a challenging environment for learning and inspiring the development of multiple skills.

Among the different e-Contents delivered through the Internet, online dictionaries are tightly associated with the notion of pedagogy (cf. Chi 2013: 165) in multiple ways. As resources of lexical knowledge, they can accompany any practice or situation that involves learners in autonomous/individual or collaborative productive and receptive tasks (a.o. Scholfield 1982; Rundell 1999) both in language and in discipline courses. The most widely acknowledged merit of online dictionaries is the easier and faster access they provide to lexical resources compared to their print predecessors (Nesi 2013: 70). A further highly important advantage of e-dictionaries is their massive storage capacity compared to the print ones, allowing for a considerable bulk of information, i.e., lexicogrammatical, multilingual, visual, audio, etc. Their extended capacity makes it possible to exploit multiple modes other than text in its traditional sense, e.g., sound, illustrations, animated pictures/images, multimedia, usage boxes, etc. Moreover, online multifunctional dictionaries may cater for the differentiated needs of learners with different access points, i.e., basic/elementary, independent/intermediate, and proficient/advanced learners (Leech and Nesi 1999: 296–303). Last but not least, online dictionaries are flexible, adaptive, and easy to update e-Contents (Lew and de Schryver 2014: 345), with potential interactive extensions, especially when they allow users to contribute new lemmas or exchange ideas/comments. This is a really crucial asset that enables compilers to accommodate the users' needs.

For all the above reasons, online dictionary access has recently signaled the depreciation of the print dictionary, to the extent that many publishers discontinue printing and move entirely to the digital medium (Lew and de Schryver 2014: 352). In the same line, it is no wonder that scientific works in lexicography are steadily replacing "looking up word" with "searching for words" (de Schryver 2012: 488, 492). However, "going online" cannot be considered as a dictionary merit by itself; in several cases, online dictionaries are just the digital versions of their print counterparts (Lew and de Schryver 2014: 352). Such a limited view underestimates the power and creativity of both lexicographic products and e-Contents in the digital school era.

The first printed pedagogical dictionaries were introduced into the Greek educational system as official schoolbooks 15 years ago, and yet dictionary use is not a widespread practice within the school setting, especially for young learners. All school dictionaries have been uploaded on the Digital School Platform (ebooks.edu.gr), however, in a static noninteractive form (only text and images). Not to mention that pedagogical specialized e-dictionaries with terminology are far from being embedded to the school practice.

To establish an online dictionary culture, new e-Contents/e-dictionaries need to be compiled and to be consistent with the needs dictated by the digital age. However, real change has to be managed as to the content and form of future e-dictionaries, so that they move away from being viewed as "isolated islands of knowledge" (Robert Amsler, cited in Lew and de Schryver 2014: 352). Amsler suggests that the future of e-dictionaries lies in the "new ways to display existing dictionary information and in connecting dictionary information to other knowledge." He continues that "It's a matter of either having lexical knowledge that nobody else has or displaying lexical knowledge in ways that are so convenient that other means of access are less attractive." At the same, it is timely to acquaint educators and students with the benefits of dictionary use within the multicultural classroom for all subjects and convince them to embrace it (Ranalli 2013; Lew 2013).

Taking into consideration the previous discussion on the need for flexible e-Contents that function as lexical knowledge resources and foster the multidimensional view of literacies, 2 years ago, we proceeded with the compilation of the online *Greek Illustrated Science Dictionary for School* (ELeFyS, www.elefys.gr), in an attempt to provide young primary school learners with a tool that may help them in developing their academic and scientific literacy within an integrated approach of language and Science learning. From its initial conceptualization, ELeFyS was intended as both a lexicographic product and a multifunctional e-Content, seeking to provide learners with stimuli relevant to all key constituents of scientific literacy (Fig. 1). In order to keep up with the evolving nature of scientific literacy – as of any type of literacy – and the differentiated learner needs in e-dictionary use, from the compilation of ELeFyS's alpha edition, we sought to eavesdrop on users' perceptions, which we considered to be a prerequisite for the development of flexible and adaptive e-Contents.

This study is in line with feedback research on e-Content delivery, as it reports on a pilot web questionnaire survey with 84 participants, conducted to evaluate users' perceptions on the design features of ELeFyS. It can be considered to be a user-related study aspiring to shed light on the utility of ELeFyS's macrostructure and microstructure and its usability, by recording both qualitative and quantitative data. We developed a three-dimensional instrument based on the relevant theoretical models, and despite the small size of the sample, we attempted a confirmatory factor analysis, in an effort to test the model's goodness of fit and predict any problems with the dataset. In the same vein, concerning reliability the internal consistency measured by Cronbach's alpha was tested for all the items and for each factor separately. For the quantifiable responses, descriptive and nonparametric statistics are offered, whereas for the qualitative aspects, a critical discussion is made. The results indicate a good model fit, a high internal consistency, and a high utility/usability rate for most of the features. Moreover, the qualitative comments reveal (a) a positive attitude toward the multifunctionality of ELeFyS, (b) adequate understanding of its constituents, and (c) interesting suggestions on future improvements. At the same time, crucial questions are posed as to the establishment of an online dictionary and scientific literature culture in Greek schools.

The structure of the chapter is as follows: In Sect. 2, we proceed with a brief description of ELeFyS. Section 3 provides the reader with some background on the concepts that are central to the analysis: dictionary and e-Content user-related studies and tools. The research methodology follows in Sect. 4. Finally, the paper concludes with a discussion of the findings followed by some implications for further research.

2 ELeFyS: An e-Content for Science Education and Language Learning[1]

2.1 Scope and User Profile

ELeFyS attempts to capture the broad conceptualization of future online dictionaries, since it has been compiled as an e-Content for the integrated development of scientific and linguistic literacy in the school context, grounding lexical knowledge in the school discipline of Science/Physics. To fulfil such an objective, generic entries include scientific terms that fall within the school subject of Physics and are likely to be encountered in the upper grades of primary and the lower grades of secondary school; however, the dictionary's coverage is not restricted to terminology, but is also expanded to the terms' respective general sense(s) and use(s).

In sum, ELeFyS constitutes a novel endeavor of combining pedagogy and specialization in order to meet the complex linguistic and cognitive/scientific needs of young school learners (native Greek or second/foreign language learners). It caters for several types of uses that target the school children's receptive and productive skills.

2.2 Innovation

ELeFyS innovates in several aspects (cf. Mitsiaki and Lefkos 2018), as it is:

- The first *Greek specialized Science dictionary* for school that fosters content-based language learning, thus promoting reception and production of both scientific terms and their respective everyday use, e.g., *ενέργεια* ("energy") in Science, but also "energy" in general vocabulary
- A *pedagogical dictionary* intended to cover the specific cognitive, cultural, linguistic, and encyclopedic needs of primary and secondary school students (11–14 years old)
- A monolingual dictionary with *multilingual lexical information*, since it establishes interlingual equivalence of scientific terms in five languages, English, Standard Arabic, Russian, Turkish, and Chinese, thus being a useful reference tool for L2 learning
- An *illustrated dictionary*, as it provides visual tools (images, animations, etc.)
- An *online dictionary* freely accessible on the Internet that circumvents the common dictionary conventions in terms of space limitation and makes imaginative

[1]For a comprehensive analytical description of ELeFys from a lexicographic point of view, see Mitsiaki and Lefkos (2018).

use of new technologies in order to ensure flexibility, user-friendliness, and a pedagogy-oriented format
- An *e-Content* with multimedia that can function complementarily to the schoolbooks or other educational resources

2.3 Macrostructure and Microstructure

To estimate the dictionary's coverage, we were based on school textbook corpora and equivalent pedagogical Science dictionaries. We opted for a systemic presentation of the entries, by arranging the concepts according to their semantic interconnectedness. Such an arrangement led to a grouping of terms into their hypernym concepts of Science, i.e., *heat*, *electricity*, etc., which is also in accordance with the taxonomy portrayed in the Greek Science textbooks. Up to now the beta edition contains 200 multi-lemmas.[2]

Each dictionary page corresponds to a distinct lemma (Fig. 2). Navigation through the dictionary is facilitated by hyperlinks to other layers of information and navigation buttons. Moreover, a user-friendly search function is provided. Finally, there is an accessibility widget overlay providing aids for users with physical, visual, or hearing disabilities, like text read aloud, text size, color contrast control, etc.

The pedagogical role of ELeFyS is ensured by the use of lexicographic symbols instead of metalanguage. The main lemma consists of sub-lemmas organized in nests. Equal weight is given to all dictionary-relevant features, such as collocational properties, word families, relationships of synonymy and hyponymy, contextual preferences, grammar, register, and etymology, to help learners replace the apparent linguistic randomness with systematicity. To assist L2 learners, recorded pronunciation files are stored for each lemma.

The definitions of scientific terms are promoted to appear at the top left side of the entry, and they are followed by the corresponding definitions of general vocabulary. Besides conventional defining formulae, contextual defining formats are used, such as full-sentence definitions, embedded in a rich microstructure. Scientific definitions are of graduated difficulty, following a ranking from the simplest (suggested for a primary observation/understanding of the phenomenon) to the most complex (leading to academic wording).

A broad spectrum of examples for every lemma is offered at the right side of the page, so that its syntactic and collocational behavior is fully illustrated. Both authentic and lexicographer-made examples are used, in order to reveal the words' patterning. Each sense and use is accompanied by illustrations, selected by specific criteria, such as the target group's age and their cultural background as well as the type of licensing (CC-BY).

[2]The compilation of an online dictionary is a dynamic process; thus, more lemmas are about to be added in the future.

Fig. 2 ELeFyS page, lemma $\beta\rho\alpha\sigma\mu\acute{o}\varsigma$ ("boiling")

Lastly, for every single lemma, thought-provoking encyclopedic, critical, experimental, and cultural stimuli are provided:

- Suggestions for experimentation that enhance critical thinking or/and intercultural sensitivity
- Hyperlinks to (a) Wikipedia, for a deeper understanding of physical phenomena and their history, (b) videos in YouTube, (c) the digital educational resources from *Photodentro* (*the Greek National Aggregator of Educational Content*), (d) multimedia available at *Noesis* (Thessaloniki Science Center and Technology Museum)
- Suggestions for dictionary use that involve students in reading, listening, speaking, and writing tasks both in Science and in language courses

3 Dictionary/e-Content Use and User-Related Studies

Dictionary use is lately experiencing an upsurge of interest, especially when it comes for online dictionaries delivered for specific user groups in specific regions (a.o. Nesi 2013; Wingate 2004; Lew and Galas 2008; Welker 2010; Gavriilidou 2013). Such research is emanating from the need to gain feedback both for the dictionaries' ease of consultation, usefulness, or functional quality and for the identification of users' needs, preferences, and dictionary reference skills. To that end, different research methods are being employed, originating from either positivistic or naturalistic approaches (Cohen et al. 2007), such as questionnaire surveys (a.o. Chatzidimou 2007; Gavriilidou 2013), interviews (East 2008), log files (Hult 2012), eye-tracking (Tono 2011), etc.; in some cases, mixed or triangulated methods are used.[3]

Questionnaire surveys are still the most widely used method, despite the criticism they receive as to their reliability and accuracy and the fact that users and compilers do not always share the same language (Lew 2002; Nesi 2013; Chi 2013). Several objections are also raised to the sample size and nature, i.e., usually small and convenient samples. However, questionnaire studies for e-dictionary evaluation or use seem to face the same dilemmas as in all fields of empirical studies. What can change the disposition toward such surveys is a more careful implementation, so that reliability and validity are ensured during the design and data collection process.

The present study falls within the scope of research evaluating the utility and usability of online dictionaries (cf. Ball and Bothma 2018). Swanepoel (2001: 167) relates dictionary quality and dictionary design, in a way that the evaluation of functional quality is not a detached or cut-off process, but "it goes hand in hand with the design process," working like a "thermostat" and thus revealing the modifications that can be made. However, utility/usability assessment of online dictionaries is not a "one-size-fits-all" process. In his extensive review of literature

[3]For a comprehensive approach, see Nesi (2013), Lew (2013) and Lew and de Schryver (2014).

concerning dictionary evaluation, Swanepoel (2008) makes it clear that the evaluation criteria may vary in scope, as they range from covering all dictionary types to being dictionary genre-specific, aiming at all the design features of a dictionary or focusing on only one specific feature. In a more recent study, Ball and Bothma (2018) identify seven evaluation criteria for e-dictionaries: *content*, *information structure*, *navigation*, *access* (*searching and browsing*), *help*, *customization*, and *innovative technologies used to manage information*.

Since ELEFYS combines the features of both an online dictionary and a wide-scope e-Content, we should make reference to usability evaluation as a general concept that embraces different kinds of digital applications. Usability is a concept mainly derived from Information Science (Heid and Zimmermann 2012), and its evaluation can be formative (Sauro and Lewis 2012, p. 10), when it aims to reveal users' perceptions about the underdevelopment material.

Several types of standardized usability tests are available, and despite their different approaches, they all engage users in a task or scenario with the under-test material and then record their subjective opinions (Sauro and Lewis 2012, p. 186). One of the most widely used instruments seems to be the System Usability Scale (SUS) (Brooke 1996), which comprises ten items; although it was initially assumed as a unidimensional tool, it was later found (Lewis and Sauro 2009) that it actually has two factors: (1) *usable* (eight questions) and (2) *learnable* (two questions). Quite similarly, one of the most highly appreciated and reliable (Revythi and Tselios 2019) tools is the Technology Acceptance Model (TAM) questionnaire, proposed by Davis (1989) and based on the idea that a user's intention to use a product is primarily affected by two factors: (1) *perceived usefulness* (six items) and (2) *perceived ease of use* (six items). However, most of the generic usability tests omit important information specific to an interface type (Sauro 2015), hence falling out of the scope of our investigation.

Moreover, distinct criteria have also been identified for the digital learning material, according to which usefulness is a two-value concept embracing (1) *pedagogical usability*, the extent to which the "functions of a system correspond with the needs of the users," and (2) *technical usability*, "how well the users are able to use the functions offered by the system" (Nokelainen 2006: 180). More recently, Papadakis et al. (2020) proposed an evaluation tool for educational applications with 13 items in 4 factors, i.e., usability, efficiency, parental control, and security.

Drawing insight from all fields of user-related studies on online dictionaries, educational e-Content, and general digital applications, we follow Swanepoel's (2008) argumentation that software usability could be correlated with the functional approach methodology for the design and evaluation of dictionaries, since they are both user-oriented, focusing their evaluation on users (while performing certain actions in the context of using a product and rating it on a functionality/usability scale).

The questionnaire survey carried out in this study is a means of formative assessment of ELeFyS. Since ELeFyS is still being compiled with more lemmas being added and decisions on content, structure, and layout being made, we conducted this pilot study in order to find out to what extent it meets the needs of its target users.

4 Methods

4.1 Research Questions

The objectives of the current research are threefold: (1) to provide some preliminary insight into the users' perceived usefulness of ELeFyS's features and the usability of its functions, (2) to develop an instrument for the assessment of ELeFyS's usefulness and usability based on previous relevant dictionary and e-Content usability tools, and (3) to seek evidence for the instrument's dimensional structure and internal consistency.

We opted for a small-scale pilot study with a restricted sample size, so as to draw valuable feedback at an early stage and to improve the quality and efficiency of a future long-term and triangulated study on ELeFyS' effectiveness to enhance the end-user's dictionary/scientific literacy/e-Content skills.

The web questionnaire (https://forms.gle/dXRqkVxuQp9Zc7Sd7) was administered to 84 informants in 3 subgroups, in-service teachers, future teachers, and primary school learners from schools and universities in Northern Greece (September 2018, March 2020), a sample size considered to be adequate for a pilot study.

The following research questions were shaped:

RQ1: Is the designed tool valid and reliable (dimensional structure, internal consistency)?

RQ2: To what extent do ELeFyS's users find its constituents useful, its layout attractive, and its functions easy to use?

RQ3: Does the perceived usefulness and usability of ELeFyS vary significantly between the three subgroups in respect to their different characteristics or roles?

4.2 Instrument

Since no other questionnaire is available, to our knowledge, for a multifunctional language and Science lexicographic e-Content, we had to construct a new instrument, adopting, though, the generic dimensions and wording of relevant validated e-Content and lexicographic tools (see Sect. 3 of this chapter). Thus, both the dimensional structure and the item specification emerge from the aforementioned theoretical constructs on user-related studies on e-dictionaries/(educational) e-Contents and multiliteracies.

First, the construct's dimensional structure draws from the usability criteria for digital learning material, i.e., *pedagogical usability* and *technical usability*. Second, the underlying factors postulated for the instrument are heavily dependent on the conceptual model of scientific literacy (as portrayed in Fig. 1); such an expanded notion of scientific literacy embraces (a) *academic (scientific) and fundamental* *(communicative) competences*; (b) *stimuli for linguistic and scientific engagement, contextual understanding, critical thinking, and learner agency*; and (c) *digital competences*. Third, the pre-conceptualized factor structure is inspired by the current need to develop and view digital dictionaries as novel pools of interdisciplinary knowledge and skills taking into consideration the following criteria: *content*, *information structure*, *access*, and *navigation*.

In an attempt to bridge the gap between theory and observation, we designed an 11-item web questionnaire. Drawing from the previous discussion, we grouped the 11 items within the following 3 factors (F1, F2, F3):

(F1) *Academic and communicative lexical information* (five items)
(F2) *Stimuli for further linguistic and scientific engagement* (four items)
(F3) *Technical usability: Ease of navigation and attractiveness* (two items)

Both the first and the second factor fall within the *pedagogical usability* criterion, and they reflect the dictionary's *content* and *information structure*. However, we considered them to be two distinct factors, as the second one reflects the novelties not found in other specialized pedagogical dictionaries, offering users food for thought and engagement in interdisciplinary tasks. The third factor falls within the *technical usability criterion* and measures ease of *access/navigation* and attractiveness. Of course, the conceptualized three-factor model deviates from the two-factor models found in generic application studies; however, the inherent multiple functionalities of ELeFyS and the specificity of its potential users favor our decision.

Each item (Q1–11) comprises two interrelated questions, a quantifiable one (1a–11a, Table 1) and a complementary one eliciting open-ended responses that justify the users' score (1b–11b). The items are followed by a final section with recommendations for improvement.

Each quantifiable item (Q1–11) scored on a 5-point Likert scale anchored with 1, not at all useful, and 5, extremely useful. The qualitative judgments are not systematically analyzed in this report, but they are mentioned sporadically as an aid in the interpretation of the quantitative data.

4.3 Participants and Data Collection

The sample comprises 59 educators (37 school teachers and 22 final-year undergraduate students/future teachers engaged in teaching practices) and 25 primary school students (convenience sample, Table 2). We made an effort to vary our sample and reach beyond the common in research university-student sample, by expanding our research to teachers and primary school learners. This was a conscious decision on our part for several reasons: learners are the end users of the e-Content, in-service teachers are the ones to introduce novel material within the school classroom, and undergraduate final-year students of Teacher Education University Departments are

Table 1 The instrument's quantifiable items

Questions	Targeted ELEFYS's features
F1 *(academic and communicative lexical information)*: *to what extent do you find useful:*	
Q1: the multiple scientific definitions?	Graded scientific definitions
Q2: the additional everyday word definitions?	Everyday word definitions
Q3: the scientific terms' examples?	Examples for scientific terms
Q4: the everyday words' examples?	The terms' respective use in everyday language
Q5: the pictorial illustrations?[a]	Pictorial and animated illustrations
F2 *(stimuli for further linguistic and scientific engagement)*: *to what extent do you find useful:*	
Q6: the etymological information notes?	Etymology boxes
Q7: the grammatical information notes?	Grammar boxes
Q8: the scientific terms' equivalents in other languages?	Interlingual equivalence tables
Q9: the encyclopedic and critical thinking notes?	Encyclopedic, experimentation, critical notes
F3 (*technical usability*): *how would you rate:*	
Q10: the overall presentation and graphical interface?	Attractiveness of layout
Q11: the search and navigation (was it easy to find what you were looking for)?	Ease of navigation

[a]Pictorial illustrations are considered to be a crucial aid to lexical meaning and exemplification

Table 2 Survey participants by role ($n = 84$)

Participant role	*n*	%
In-service teachers	37	44
Future teachers	22	26
Primary school students	25	30
Total	84	100

the ones who are mostly acquainted with innovative interdisciplinary approaches in teaching and learning.

Fourteen participants were excluded from the analyses, as their responses were only partially filled or their comments seemed to be out of context. Written consent to participate was obtained from all participants (adult teachers and the young learners' parents).

All the participants filled in the 11-item questionnaire administered after their involvement in (a) training seminars on scientific literacy (in-service and future teachers) or (b) exposure to content (Physics) and language instruction (students). Before completing the questionnaire, all subjects were familiarized with ELeFyS's features during a 1-h guided (in-person and distance) session of browsing. In this way, we attempted to acquaint users with ELeFyS and eliminate the possibility that responses are influenced by unclear wording or other inconsistencies.

4.4 Data Analysis and Results

4.4.1 Content Validity

Content validity was established after consulting external expert reviewers, both from the field of Lexicography and from the field of Science Education.

4.4.2 Construct Validity

A confirmatory factor analysis using AMOS 26.0 was run, in order to test the fit of the three-factor model. Six indices were used to evaluate the model's goodness of fit: chi-square, chi-square/*df* ratio, *p*-value, goodness-of-fit index (GFI), comparative fit index (CFI), and root mean square error of approximation (RMSEA). As displayed in Table 3, a nonsignificant *p*-value is obtained (.152), indicating an acceptable fit (Byrne 2001). GFI and CFI are above 0.9 or close to 1, and the RMSEA value is less than 0.06, which is further evidence for a good model fit (Schumacker and Lomax 2012; Hu and Bentler 1999). The previous results insure the validity of our construct.

4.4.3 Internal Consistency and Reliability

To check the instrument's reliability, we calculated (a) the Cronbach's alpha coefficients and (b) the correlation between the individual items and the total score for all items (Table 4). High internal consistency is ensured for all factors except for the third one (technical usability) which is at the cut-off point (0.689), a finding to be further discussed.

Table 3 Goodness-of-fit indices of the three-factor model

χ^2	df	χ^2/df	p	GFI	CFI	RMSEA
50.291	41	1.22	0.152	0.902	0.97	0.05

Table 4 Indices of internal consistency of the administered questionnaire

	Total	F1	F2	F3
Correlation with total score	1	0.908	0.905	0.663
Alpha coefficient	0.896	0.842	0.842	0.689

Table 5 Means (*M*) and standard deviations (SD) per group ($n = 84$) and factor (F1–F3)

	M (SD)		
Factors	In-service teachers ($n = 37$)	Future teachers ($n = 22$)	School students ($n = 25$)
F1: academic and communicative lexical information	4.44 (0.48)	4.55 (0.50)	4.18 (1.03)
F2: stimuli for further linguistic and scientific engagement	3.99 (0.62)	4.00 (0.87)	4.33 (0.98)
F3: technical usability	3.84 (0.74)	4.22 (0.65)	4.22 (1.02)

4.4.4 Descriptive Statistics and Between-Group Differences

Table 5 displays descriptive statistics (means and standard deviations) for each factor and for each group of informants.

Notably, the overall picture does not exhibit intense variation. In almost all cases, the mean values are greater than 4.00. This can be interpreted as a very positive user perspective, but at the same time, it can be indicative of a ceiling effect, since accumulated percentage of scores 1, 2, and 3 is between 10% and 30%, thus leaving a spacious 70–90% for scores 4 and 5. Despite the well-acknowledged impact of a ceiling effect on reliability, the bunching of scores at the upper level could be acceptable for an instrument that assesses a novel e-Content which integrates dictionary, encyclopedia, school textbook, multimedia, and other functions and might differ from the conventional unifunctional print school material the users are used to.

As displayed in Fig. 3, the differences in scores between the three groups are significant at $p < 0.05$ for two out of three factors.

More specifically, all three groups seem to share similar perceptions on the usefulness of F1. It is worth mentioning that the primary school learners exhibit a lower mean (4.18) compared to both the teacher groups (around 4.5) and more divergent opinions as denoted by the high *SD* value (1.03). For F2 the in-service and future teachers' preferences seem to converge again ($M = 3.99$, $M = 4.00$); however, the primary school students seem to be more enthusiastic ($M = 4.33$), despite their high divergence of opinion ($SD = 0.98$). A quite reverse finding was obtained for F3; this time the future teachers and the primary school students seem to agree on the usability of ELeFyS ($M = 4.22$), whereas in-service teachers are more reluctant ($M = 3.84$).

As already mentioned, an interesting pattern observed in Table 5 concerns the standard deviation values. A closer look at the data shows a tendency for increasingly diverging opinions as we move from the in-service teachers to future teachers and finally to primary students. This finding might be correlated with the fact that in-service teachers are greatly influenced by their teaching experience, while future teachers are just beginning to get involved in teaching practices.

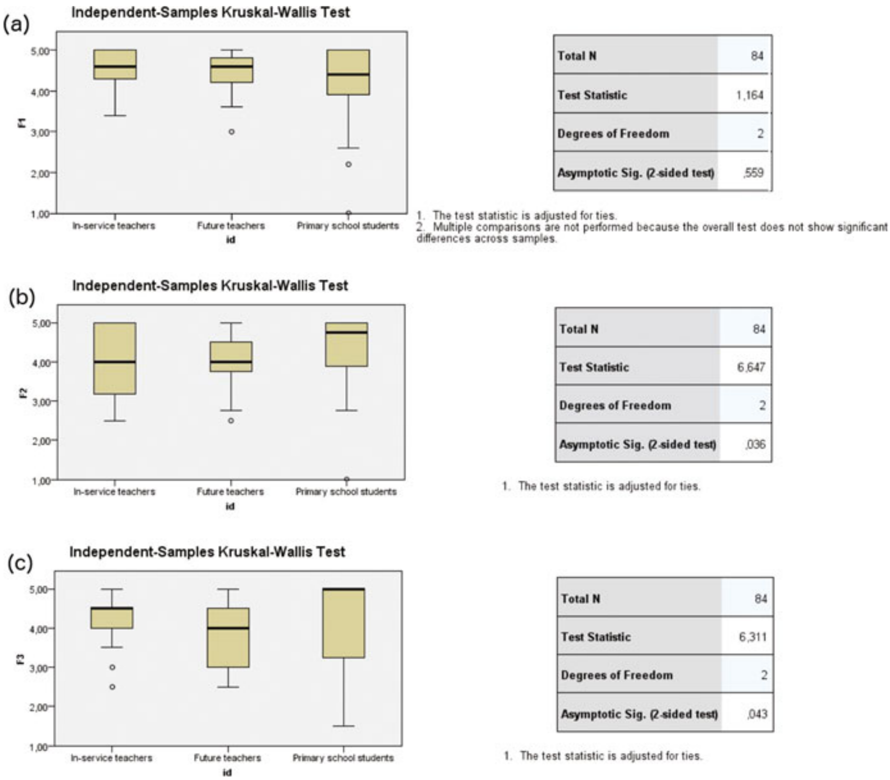

Fig. 3 Independent-samples Kruskal-Wallis test displaying between-group differences by factor (a-F1, b-F2, c-F3)

Another influential factor might also be the obvious age difference between these three sample groups.

We proceeded with statistical analyses using SPSS software (ver. 25.0) to examine whether the recorded preferences of the three surveyed samples display significant differences. The results of the one-way Kolmogorov-Smirnov test for each participant group suggested that the item scores differ from the normal distribution ($p < 0.05$).

Since our data were not normally distributed, we adopted the nonparametric independent samples Kruskal-Wallis test to check for between-group significant differences in Likert scale scores.

As displayed in Fig. 3, the differences in scores between the three groups are significant at $p < 0.05$ for two out of three factors.

More specifically, the differences in scores for F1 are not significant. The between-group differences appear to be significant for both F2 ($p = 0.036$) and F3 ($p = 0.043$).

4.4.5 Qualitative Responses

The data collected from the survey's open-ended questions were subjected to qualitative content analysis, in order to identify response clusters and trends. Although the qualitative data analysis is not part of this chapter, mentioning some of the participants' judgments will provide support for the quantitative data presented earlier.

For example, the design feature investigated in Q3a (examples for the scientific definitions, F1) was highly appreciated from all participants. In Q3b, the informants had to comment on the perceived purpose of this feature. Most of the comments exhibit a very positive to almost enthusiastic implied acceptance, e.g., "the scientific definitions are crucial for constructing the meaning," "they are fostering the ability to incorporate scientific terms in written and oral expressions," "they can help in retaining related meanings for much longer," and "they can help us (students) to understand the scientific terms."

Another feature worth mentioning is the perceived purpose of the pictorial illustrations, investigated in Q9a (F1). Some typical comments from Q9b were "illustrations create a friendly environment and trigger the interest," "illustrations can be much helpful for the visual type learners," and "illustrations can be an aid for the understanding of the concepts."

All the aforementioned comments are more or less being repeated in all three sample groups. Even students express similar views in their own wording.

Finally, on the additional free comment section, participants express their overall positive attitude (consistent with the overall picture of the qualitative data). Comments like "keep it up this way!" or "thank you for your effort" were the most common ones. Some informants would make suggestions like "I would like more lemmas to be included" or "it would be nice to add the pronunciation function in all presented languages."

5 Discussion

Despite its small-scale pilot nature, this study (a) reveals several interesting considerations on the users' perceived utility and usability of ELeFyS and (b) provides valuable feedback for the development of the ELeFyS questionnaire but also for instruments that assess the usefulness and usability of multifunctional lexicographic e-Content.

As far as the development of the ELeFyS questionnaire is concerned, the procedure was not free from restrictions. In the first place, we ran an exploratory factor analysis using principal axis factoring with oblique rotation to investigate the factor structure and see how the variables relate and group based on inter-variable correlations. The analysis revealed that the instrument has a two-factor structure grouping together Q1 to Q9 and Q10 to Q11. Unfortunately, in this way, F1 explained about 50% of the total variance (61%). This pitfall is also reflected in the lower Cronbach's α coefficient for the factor of technical usability (0.689). However, as the sample size of this initial pilot study is small, we decided to follow our theoretical rationale, thus to postulate three correlated factors. Moreover, we are aware that our sample is marginally sufficient for a confirmatory factor analysis and an investigation of the tool's internal consistency. Of course, since the completion of the questionnaire follows engagement in tasks, seminars, and practice with ELeFyS, a much bigger sample could be a difficult endeavor. In any case, although the analyses revealed a good fit of the model and adequate to high reliability, these results point at a slight revision of the instrument (more specific items for F3), a subsequent revalidation and implementation (bigger sample).

Moving to the analysis of the users' scores and preferences, the overall picture is striking in their positive stance toward ELeFyS, as proved by the high means for all factors and sample groups. To go in more depth, we should mention that all groups seem to reward both the theoretical and the practical/more experiential constituents of ELeFyS (definitions, examples, and pictorial illustrations, F1). On the other hand, both in-service and future teacher groups appear to appreciate the linguistic aids of ELeFyS (usage boxes for etymology, grammar, F2) less than young learners, as if language may not interfere with Science Education. Such a finding might be indicative of a more dissociated cut-off approach of language and discipline courses in the Greek school, despite the voices of scholars who argue for an integrated approach of language and content. At the same time, this finding can be interpreted in terms of the dictionary referential skills of both (in-service/future) teachers and learners. Therefore, it seems that either the teachers view ELeFyS as an e-Content for Physics, where language takes less space, or they are less aware of the benefits that a dictionary's constituents can offer to the learners. This takes us undoubtedly to the necessity to establish an e-dictionary use culture in Greek schools.

We should also comment on the more conservative view put forward by teachers of an e-Content that functions also as a lexical knowledge resource. A striking finding is that young learners reward the existence of interlingual equivalents and critical stimuli (F2), whereas in-service/future teachers seem to be rather reluctant in acknowledging their utility. A disappointing admission to be made is that e-Content with multilingual references is not a common practice in the Greek mainstream classroom yet. Maybe it is the case that teachers see no point in offering multilingual scaffolding for emergent bilinguals, when they are far from understanding and producing more complex academic/scientific language. At the same time, they appear to be less informed on or less convinced of the utility of stimuli for the students' critical, experimental, encyclopedic, and cultural engagement. It is possible, though, that teachers view such an extension as distractive from the content-oriented curriculum that is heading to the acquisition of scientific concepts and phenomena. On the contrary, the students who participated in the research appreciate the most these features of ELeFyS, possibly revealing their need for a plurilingually and critically oriented school reality.

Finally, in-service teachers appear to be less enthusiastic on the technical usability of ELeFyS, a finding possibly attributable to many reasons. Luckily enough, the teachers' open-ended responses are explicit in expressing their needs for a more systematic training in the use of e-Contents.

The qualitative data gathered for this web questionnaire survey shed more light on the quantitative analysis. The participants seem to acknowledge in their open responses the benefits of scientific definition gradedness, despite the fact that they do not always assess it as an extremely useful feature (learners). They also seem to understand the advantage of the parallel provision of everyday meanings and use. Moreover, they are expressed very positively on ELeFyS's layout/presentation and navigation features, commenting on its user-friendliness and attractiveness (especially future teachers and learners). In many cases, they contribute comments such as "Keep it as it is" or "There is nothing to modify." Even in the case of less popular features (i.e., tables of interlingual equivalents), they do not suggest their wiping out of the dictionary, but they acknowledge they could function effectively in specific situations (teachers).

In sum, the feedback we gained through the current pilot survey is a positive one. At the same time, we are obliged to reflect on the features of ELeFyS that appear to be less perceived as useful. This is a quite complex process for several reasons. The most crucial of them is put forward by Lew (2011: 9–10): the evaluation of a given feature does not assess obligatorily "its inherent fitness of purpose," but it also reveals the extent to which "the users are habituated" to exploiting such a feature. However, if they are not well-acquainted or habituated to it, it is possible that they will not be positively affected by the novelty. Such a statement can be verified, if we take into consideration that both the in-service/future teachers and the students of the current study have been partially engaged in training seminars and content- and language-oriented courses, which means that they are not still habituated to these novelties.

Hence, the contribution of this research to the field of e-Content evaluation is that it suggests a generalizable design format for specialized pedagogical dictionaries and their usability tools, one that favors the three aforementioned factors.

Moreover, these findings that are undoubtedly treated with caution as they arise from a small-scale research provide insights in the future research for ELeFyS. This has to be a longitudinal research that combines the investigation of the informants' scientific literacy and dictionary reference skills and their training/habituating practices. As soon as the reliability of F3 (technical usability) is fixed by adding more specific questions, the questionnaire is planned to be revalidated and correlated with measures of task effectiveness and efficiency. It goes without saying that in such a research, several methodological tools are to be exploited apart from questionnaire surveys. Thus, future research has to be informed by the limitations of the current study, i.e., the small convenient sample, the less elaborate factor on technical usability, and the fact that users' expertise in dictionary use and scientific literacy was not surveyed.

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Microgenetic Analysis of the Educational Robotics as Mindtools: A Case in the Construction of the Concept Speed

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1 Introduction

The rapid development of technology in the twenty-first century has led to the introduction of plethora of innovative technologies in the educational settings. Empirical research findings report that educational robotics (ER) is one of the promising technologies that has potential as a learning and teaching tool (Anwar et al. 2019) to significantly impact on students' academic and social skills (Menekse et al. 2017). As a result, ER has drawn the attention and interest of numerous researchers and teachers in all educational levels. Educational robots more often meet the form of constructible and programmable artificially intelligent devices that, with a social constructivism-constructionism aspect, provide dual modes of representation (Sullivan and Heffernan 2016), combining physical and mental experience of interaction with the environment and the tools that it contains (D'Amico et al. 2020). In particular, they are able to create an authentic and attractive learning environment which engages the students in both real situations (constructing real, tangible models of the physical world and experimenting on and with them—3D representation) and virtually ones (programming and manipulating the robotics models via the computer—2D representation) (Sullivan and Heffernan 2016).

Many researchers have focused on the innovative technology of ER, yet highlighting its value mainly as a learning object (i.e., learning about robots) (e.g., Sullivan and Bers 2016) and exploring often specific engineering concepts (e.g., Ariza et al. 2017). In addition, ER has been widely utilized as a tool for the development of the twenty-first-century higher-order skills, such as critical thinking,

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problem-solving, self-directed learning, knowledge construction, creativity and innovation, communication, and collaboration (e.g., Eteokleous et al. 2019), or for the achievement of general multidisciplinary goals especially in STEM framework (e.g., Socratous and Ioannou 2018). Similarly, in a recent extensive review of 147 eligible studies on the use of educational robots in STEM concepts, most of them (98 studies) highlighted the general benefits of robotics usage in K–12 education (learning experience improvement, inquiry, and other developmental competencies) or addressed creativity and student motivation without focusing on more specific aspects (Anwar et al. 2019). Consequently, review researchers argue that apart from the general approaches, there is a need to determine the specific benefits which have been achieved through robotics implementation in K–12 formal and informal learning settings. They state that different assessment methods would be useful and align with Streveler and Menekse (2017), who emphasize the need of a more fine-grained approach to understand the role of ER within appropriate contexts and activities.

Efforts to detect the contribution of ER as a learning tool especially in the subject of physics are reflected in the systematic review of Sullivan and Heffernan (2016), within 21 eligible studies that utilized robotics construction kits in P–12 STEM learning. They call for more qualitative research to assess learning gains specific to the hands-on nature of the activities. Additionally, Socratous and Ioannou (2018) point out that most of the existing literature is descriptive and focuses only on the learning outcomes without examining the processes and conditions under which they are accomplished or illustrating the learning process in progress (Charisi et al. 2020).

Papert (1993) has characterized computers as “objects to think with” (p. 11), a claim that aligns with the computers’ aspect as *mindtools* (cognitive tools), initially introduced by Jonassen (2000) who had the intention to give them a role of “intellectual partner” that extends the cognitive power of the learner towards high-order thinking and learning. Research from the broader field of educational technology as mindtools concentrates mainly on the emerging learning effects via technological tools without capturing sufficiently the complex interrelationships between them and learners, i.e., their roles as intellectual partners, and the partnering processes, indicating the need for deeper research focus (Kim and Reeves 2007). Regarding the use of learning tools as mindtools, technological and non-technological, Pakdaman-Savoji et al. (2019) conducted a systematic survey of 196 eligible studies from 1982 to 2018. They concluded that the term mindtool (or cognitive tool as well), although it has been used extensively in educational research and theory, has been detected to be extremely general and fuzzy, lacking in definition and description of the characteristics that determine it. Thus, considering the vast number of technological advancements, the need for reexamination of the mindtool concept emerged (Drew 2019).

Educational robots can be considered as mindtools (Eteokleous 2019; Mikropoulos and Bellou 2013). Several research studies have detected the contribution of ER as an effective learning tool while focusing on specific concepts of certain subjects as physics and more specifically kinematics (e.g., D'Amico et al. 2020). Towards the same direction, studies have integrated ER as an effective learning tool under the term of mindtool (Eteokleous and Ktoridou 2014) or cognitive tool (Eteokleous 2019) for developing elementary students' cognitive skills towards non-STEM concepts and addressing its potential to achieve specific learning goals and a student-centered environment. Mikropoulos and Bellou (2013), aiming to give a stronger evidence of mindtool characteristics, utilized educational robots in two case studies as medium for developing programming and basic kinematics concepts (study of simple motion and velocity by six elementary students). They concluded that ER can be used as powerful mindtool for programming and physics teaching and learning, supporting knowledge construction through the design of meaningful authentic projects, learning by doing in both virtual and real worlds, facing cognitive conflicts, and learning by reflection and collaboration.

The mainstream approach of the aforestated studies, in which they utilized ER either implicitly or explicitly as mindtool focused on the product, i.e., learning benefits of students, yet in a quite general and descriptive macroscopic level, without having been paying attention, within a more microscopic lens, to the potential different uses and dimensions of its contribution as mindtool in cognitive trajectory of students. Nevertheless, the microgenetic analysis approach yields unique information about how learning occurs, i.e., it focuses on the process (Siegler 2006). More specifically, a microgenetic analysis approach to a learning procedure is a robust form of analysis (Kuhn 2002), i.e., a high-density observational research technique through which the researcher by intensively collecting and analyzing interactions (among peers and tools) over a given period of time attempts to track the trajectory of a cognitive change in some activity (Siegler 2006; Sullivan et al. 2015). This level of analysis, therefore, allows the researcher to investigate not only students' knowledge (what they know) but also the processes/patterns of change (how they get there) while it occurs, offering a way of exploring learning that goes beyond the pretest/posttest methods (Brock and Taber 2017).

Thus, the aim of the current chapter is to present a novel, to our knowledge, microgenetic analysis approach towards the study of the use of ER as mindtool in the physics discipline. A case is presented with regard to the construction of the concept of speed by elementary students.

The chapter is organized as follows: The next section, enriched with theoretical orientation, provides a useful background concerning the aforementioned concepts. The third section introduces the proposed microgenetic analysis approach, whereas the fourth section, paradigmatic in character, exemplifies and discusses the way the proposed approach could be realized within a case study of the construction of the concept speed by elementary students. Finally, the fifth section summarizes the core issues of the proposed approach and highlights extensions and future work.

2 Background Information

In this section, a theoretical background is provided to facilitate the reader.

2.1 *Learning with Technological Mindtools*

The notion of mindtools/cognitive tools has been widely used since 1980 in research, practice, and theory relating to learning and instruction. As Pakdaman-Savoji et al. (2019) state, gradually the terminology and the conceptualization of mindtools/cognitive tools have been differentiated and featured multiple new meanings. Moreover, in their work, they trace the theory of cognitive tools along with learning and development from Vygotsky and Soviet psychology through its use in current educational technology and learning design. Hereinafter, the term mindtool will be used for the needs of this chapter.

One of the crucial principles in using mindtools is that learners learn with technology and not of/from technology (Jonassen 2000). In that sense, knowledge is not teacher- or technology-controlled, but is actively (engaging the mind) constructed by the learner through technology (Papert and Harel 1991), shifting the traditional role of technology as teacher/tutor to technology as partner in learning process (Jonassen 2000). When mindtools function as catalysts for active, constructive (within constructivism perspective), intentional, cooperative work on authentic tasks, they can become the tools for meaning-making, tuning students' internal mental models (Jonassen and Cho 2008). According to Jonassen (2000), mindtools are "computer-based tools and learning environments that have been adapted or developed to function as intellectual partners with the learner in order to engage and facilitate critical thinking and higher order learning" (p. 9). More specifically, they can play the role of cognitive partners contributing to the division of labor, between them and the learners, i.e., them elaborating data (tasks they perform better than humans) and the learners recognizing, judging, and organizing upon the outcome of this elaboration (tasks they perform better than computers). Ultimately, they engage learners in critical and reflective thinking, i.e., the deep and hard deliberative and inferential thinking about the subject (making sense) which follows the interaction and the automatic experience with the environment and the artefacts. Thus, computers, in the above framework of mindtools, function as cognitive scaffolders, as they exceed the capacity of the human mind, amplifying, reorganizing, and fundamentally restructuring it, and help it to achieve what it would otherwise be unable to achieve.

Pakdaman-Savoji et al. (2019), concerning the technological advancements and the complex nature of mindtool concept, conducted an extended survey towards its conceptualization and clarification (including the broader term of cognitive tools) in research and theory relating to learning and instruction and concluded with three core characteristics/attributes of mindtools:

- *Representation*, i.e., a mindtool is a system of concepts and operations in a form of technology that supports goal-oriented cognitive processing. More specifically, a mindtool should represent knowledge in a way that clarifies confusing and challenging concepts in which students usually manifest common misconceptions.
- *Interactivity*, i.e., a mindtool facilitates students to frequently interact or refer to it along the process of the tasks. As a result, students internalize its related concepts and operations, reorganize their cognitive schemas, and may eventually be able to complete similar tasks without an external support.
- *Distributed cognition*, i.e., a mindtool, as Jonassen's cognitive partnership, supports students to complete a task by distributing to the tool computational operations required by the task (such as calculate, store, and retrieve information) and allocating the deeper and harder processing to them.

The above three attributes describe how mindtools can be designed, evaluated, and redesigned and researched to promote learning.

2.2 Learning with Educational Robotics as Mindtools

Educators need to design learning environments enhanced by ICT, such as ER, in which students have the opportunity to experience them as mindtools within their learning processes (Eteokleous 2019). Although Jonassen (2000) does not explicitly involve ER among the suggested types of technological mindtools, it seems that it could play effectively the role of a mindtool (Eteokleous 2019; Eteokleous and Ktoridou 2014; Mikropoulos and Bellou 2013), since it features the mindtools' substantial principles towards learning with technology. More specifically, Mikropoulos and Bellou (2013, p. 11) detected five characteristics of ER as mindtools in physics teaching and learning as a result of their case study in kinematics (in parenthesis our indicative mirroring to Pakdaman-Savoji et al.'s (2019) characteristics of mindtools):

- Construction of knowledge through the design of meaningful projects and the students' powerful ideas using authentic paradigms (*representation*)
- Learning by doing in both virtual (by programming) and real worlds (by constructing the ER and studying its motion) (*representation*, *interactivity*, *distribution*)
- Learning by facing cognitive conflicts through the comparison between causes and results during programming the ER's motion (*representation*, *interactivity*, *distribution*)
- Learning by reflection and the representation of the knowledge, discussing the observations (*representation*)
- Learning by conversing through collaboration, discussion, and argumentation (*representation*)

From the aforementioned, it is evident that ER provides the affordances to function as mindtool, yet on the basis of the teaching/learning design.

2.3 The Microgenetic Method of Analysis

The microgenetic approach allows the researcher to assess in a fine-grained way changes in the variables of interest. In particular, the initial (input) and the desired (output) cognitive state entails a change in student's understanding of a concept, throughout a time span. Thus, considering as variable of interest the change in the student's understanding of a concept, a microgenetic analysis can be employed to capture possible changes. During this analysis, the following five dimensions are detected (Siegler 2006):

- *The source of change*. It refers to the causes of the cognitive change. Learning design decisions on sources of change may provoke internal (e.g., motivation, collaborative climate) and/or external stimuli (e.g., the tasks, the ER use, other students when collaborative sessions of work are foreseen, and the teacher depending on the type of scaffolding that is provided).
- *The path of change*. It refers to the cognitive sequences that are followed by the student in order to understand a concept. The depiction of the path of change includes periods of static intervals (Brock and Taber 2017), when there is not any cognitive change, and periods where a change takes place. Hence, the detection of the static intervals is crucial towards capturing the presence of change.
- *The rate of change*. It refers to the rate of discovery, i.e., the amount of experience before the frequency of the use of the new understanding of the concept reaches its asymptotic level (scientific delivery of the concept under study), namely, the rate of uptake.
- *The breadth of change*. It refers to how widely the new acquired understanding can be generalized to different problems of the same task, e.g., to real-life problems.
- *The variability of change*. It refers either to the different strategies that are used by the student or to the differences among students.

In order to detect evidence to represent the above dimensions of conceptual change, a data sampling procedure is needed, e.g., through video recordings, along with tests, clinical interviews, researcher's notes, etc. Analysis of the collected bulk of data may provide a high resolution of representation of change. Siegler (2006) proposed three suggestions as far as the sampling is concerned. The first suggestion is that the sampling must cover the time span in which the change is expected to take place. However, the researcher by no means can define a priory this time span but from evidence from other studies and/or piloting (Brock and Taber 2017). Moreover, other issues that also need to be accounted may frame the duration of a learning intervention (e.g., the availability of the students), posing a risk in the possibilities for a conceptual change to occur.

The second suggestion is that within this time span, the density of the sampling should be relative to the rate of change. Hence, two rates are needed to be considered, the rate of change that is expected to be manifested in the time span and the rate of sampling so as the static intervals and the conceptual changes can be captured.

Finally, the third suggestion is that the data of the sampling procedure should be analyzed in detail in order to detect the mechanisms that caused the change.

Such analysis is performed on the basis of quantitative and/or qualitative data. Moreover, graphical representations are used to provide insight to the learning procedure, e.g., the Chronologically-Ordered Representation of Discourse and Tool-Related Activity (CORDTRA), that was used for the analysis of the evolution of computer-supported collaborative learning (Hmelo-Silver et al. 2011). In particular, CORDTRA is a scatterplot in a commercial spreadsheet program that presents the chronological evolution of coded data at different levels of interest stacked vertically, i.e., plotted on one timeline in parallel.

According to Parnafes and diSessa (2013), the microgenetic approach may be combined very well with case studies. The case study approach focuses on the individual change and tries to analyze it in depth. Moreover, it is argued that this approach can be extended to combinations of the individual analysis in order to examine group differences and study transitions of more than one individual (Lavelli et al. 2005). Although case studies have been criticized for the lack of generalizability, it is argued that microgenetic case studies have stronger ecological validity and allow for deeper insights in the phenomenon under investigation (Parnafes and diSessa 2013).

The microgenetic approach has been extensively used in research work concerning conceptual change in science education. An extended review of such work is presented by Brock and Taber (2017). Yet, this body of research work does not include the use of ER in the learning design. On the other hand, Socratous and Ioannou (2018) focused on a so-called micro-level examination of students' discourse, interactions (with peers, the teacher, and the robot), and students' deliverables (software programs and worksheets), in the STEM field. Through data coding, this work reveals conditions that appear to relate to coded levels of knowledge construction. Moreover, a CORDTRA graphical representation is used to visualize the approach, yet depicting the robot in an undifferentiated way (same symbol) as far as its function as a mindtool is concerned throughout the time span of the learning intervention. To our knowledge, there does not exist any study involving microgenetic analysis of the contribution of robot as mindtool to the conceptual change. Towards this direction, a microgenetic analysis approach is proposed in the next section of this chapter.

3 The Proposed Educational Robotics Microgenetic Analysis Approach

In this chapter, the microgenetic analysis method is proposed that may highlight the contribution of the ER use as a mindtool towards conceptual change within a learning context. In Fig. 1, the overall approach is depicted.

In particular, the proposed Educational Robotics Microgenetic Analysis approach (ERMA) foresees three basic modules.

The first module is the learning intervention (LI) design where decisions are taken concerning the LI, as the use of ER takes place in a learning context rather than in a vacuum. They are based upon existing knowledge and the aforementioned theoretical background in order to provide a learning environment with increased possibilities for ER to function as mindtool (e.g., Mikropoulos and Bellou 2013; Pakdaman-Savoji et al. 2019) and to promote conceptual change so as the understanding of a concept by the student is close enough to its scientific definition. Moreover, measures should be taken concerning the microgenetic character of the study in order to secure the rate of both conceptual changes and data sampling.

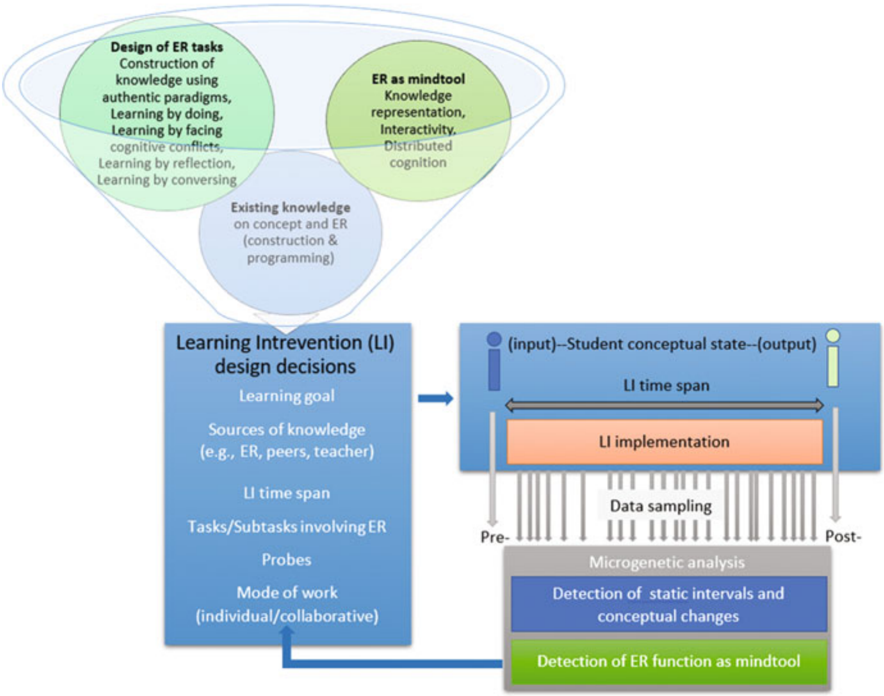

Fig. 1 The proposed Educational Robotics Microgenetic Analysis (ERMA) approach

In particular, upon the learning goal definition, distributed sources of knowledge that will be provided are selected. Along the time span that will be decided as discussed in the previous section, tasks (Ts)/subtasks (STs) that will be allocated to students are designed. More specifically, the T/ST design is based upon the didactics of the specific concept domain so as to provoke cognitive change. On the other hand, as Brock and Taber (2017) argue, a study that encounters similar tasks and repeated probes is not considered as microgenetic. Thus, a variety of T/STs should be foreseen as probes to provoke cognitive change and transfer the acquired knowledge to other contexts. Finally, decisions are made concerning the mode of work (individual/collaborative) per T/ST.

The second module is the implementation, which refers to issues of student sampling, their preparation if needed (construction and/or programming of ER), and the realization of the cognitive baseline for every student concerning the concept under study.

Finally, the microgenetic analysis module taking place at the micro-level is much more informative than pretest/posttests at the macro-level, as it zooms in the cognitive effort of the student and justifies possible changes.

Concerning the graphical representation of the results, the CORDRA diagram was proposed and used in collaborative sessions, where the initiation and end of a collaborative session are common for all the participants. Yet, when the LI foresees an interplay between individual and collaborative sessions of work in a group of students, the possible different duration of the individual work may lead to more complicated depictions. Moreover, the scatterplot is a more quantitative approach of rigorous flow of spots in time, but in the case of the conceptual change, this might result in overfitting of data, e.g., in the case of static intervals that might also increase the level of complexity of the depiction. Considering the CORDRA approach as a low-level analysis representation (an analysis that takes place at the background upon sampled data), in this work a graphical representation is proposed, namely, Qualitative Chronologically Ordered Representation of Educational Activity (Q-COREA). Q-COREA is a qualitatively reduced representation of a scatterplot like CORDRA, where there exists the chronological order of the codes, yet their representation is normalized in the max duration of T/ST in the individual modes of work. This representation brings at the foreground the chronological order of the codes detected per individual, him/her working either individually or collaboratively using the time variable as an indication of order. This approach allows for easier comparisons of conceptual changes between the members of a group and per groups. Thus, the Q-COREA provides a simple depiction at a higher level of abstraction that can contribute to a more hermeneutical approach to the interpretation of the results of the microgenetic approach across different modes of work, per student and per group. The Q-COREA can be materialized easily in spreadsheets, word processing software, etc. and can include as many levels of coding the researcher extracts from the data (e.g., cognitive static intervals and changes, ER function as mindtool, etc.).

In the case of the ER, such microgenetic analysis moves away from the perspective that it functions uniformly as mindtool throughout the LI and seeks for richer information about attributes of this function. So, the microgenetic analysis effort shifts the more surfaced pre-/post-approaches to a more fine-grained assessment.

Obviously, there is a high dependence between the above modules of ERMA, so the informative character of the microgenetic analysis may trigger a new circle of LI design. The overall ERMA approach provides a more detailed insight in the learning procedure when the ER is expected to serve as a learning companion towards conceptual change.

In the next section, the speed case study was used to illustrate the potentiality of the ERMA approach.

4 The Speed Case Study

ER can be meaningfully employed to help develop students' perception about motion (Sullivan and Heffernan 2016). Through simple constructions, such as a robotics car (RC), they can simulate the real ones and use them in short-term learning interventions to conduct experiments and explore basic kinematic concepts, such as distance, time, linear/angular velocity, and the relationships between them (Arlegui et al. 2009). As children from an early age have motion experiences on a daily basis, they often deal with the concept of "speed" and inevitably form prior ideas about it (Kadir et al. 2011). Although a daily concept, it is considered one of the most difficult concepts in the upper grades of elementary school, according to Gravemeijer et al. (as cited by Khikmiyah et al. 2014). This may be due to the fact that the concept of *speed* (u) is a derivative quantity that encompasses a relationship between two variables: *distance* (d) and *time* (t) (Piaget 1970). However, they usually learn this concept mechanically through formalistic mathematics ($u = d/t$) as "distance divided by time elapsed," and as a result, they acquire the procedural knowledge of the concept without the essential conceptual background (Khikmiyah et al. 2014).

In the next subsections, the speed case study was used to illustrate the proposed ERMA approach.

4.1 Design and Implementation of Learning Interventions (LIs)

A series of three LIs, involving ER use, were designed towards the conceptual construction of the concept speed. Towards this aim, six male students in Greece, 12 years old (6th grade), were purposefully selected by the researchers, upon their parents' consent, as they were highly experienced in the use (construction and programming) of the Lego Mindstorms Education EV3 (as being participants of an informal robotics group), but had no prior concrete knowledge of the concept of speed.

The three successive LIs took place in an informal setting with a total duration of 2 months (August–September 2017). This time span, although restricted by the participants' availability, was estimated by the researchers as adequate to produce rich data. Each LI lasted approximately 90 min, and each of the first two was followed by an interval of 2 weeks. The students, separated in two groups (three students in each), dealt with closed and open-ended tasks/subtasks (Ts/STs) involving the robot, with specific goals and stepwise expected learning outcomes per T/ST, while working individually and/or collaboratively. Considering the variables *distance* (d) and *time* (t) that are involved in *speed* (u), the first two preparatory LIs, LI1 and LI2, aimed at the elaboration of the concepts distance and time, respectively, and the required learning outcomes were assured through pre- and post-assessments (meso-level) so as the students could initiate the LI3 about speed from the same cognitive baseline.

Particularly in the LI3, the expected outcomes from the six Ts (Table 1) focused on the intuitive realization of u as "fastness" (T1) and the qualitative correlation of "fastness" with d and t variables (T2) (preparatory phase of LI3). Subsequently there were measurements, collection, and tabulation of data of d, t, "fastness" (T3/ST3a), the realization of the calculation of u from the extracted data (T3/ST3b), the use of scientific terminology for u (T3/ST3c), and the realization of the variability of d, t, and u (T4). Finally, this intervention foresaw the scientific modeling of u through inferential thinking (T5) and the implementation of the acquired knowledge about u calculation (T6) (elaboration phase of LI3). Generally, informed by the didactics in the area of science teaching, this effort was based on intuitive knowledge about u upon which construction of a more sophisticated scientific approach was expected.

From the robotics perspective, prior to the preparatory LIs, each group of students constructed one Lego Mindstorms Education EV3 robot simulating a real-world car, i.e., a RC. However, considering the fact that the students did not know the mathematical formulation to calculate u from the beginning, they were not expected to program the RC in the T3/ST3a. Thus, it was provided to them as a pre-programmed RC concerning the calculation and the display of the value of "fastness." However, along with the rest of Ts, they could experiment with it by inserting different values of d, t, and the "throttle." Finally, in T6, they were asked to calculate/display the u via programming of the RC, an effort that was also designed to elicit information, serving as an indicator of the construction of knowledge about u.

The flow of the Ts/STs along with the mode of work was guided by prepared paper worksheets that were provided to the students at the beginning of each T. In particular, these sheets assigned each T/ST to the students and defined the mode of work. Moreover, it served as a probe, as it elicited written data in the form of hypotheses, opinions, suggestions, definitions, calculations, reflections, and syntheses of common work in collaborative Ts/STs. In particular, by the end of T6, a posttest was performed to check if near transfer of knowledge could be performed

Table 1 The learning design of LI3 in the speed case study

Preparatory phase	T/ST	Expected cognitive outcomes
	T1	
	Realization of correlation of the RC's "throttle" to "fastness" upon different simple programmed motion trials by the students	Intuitive realization of *speed* as "fastness"
	T2	
	Realization of correlation of d and t to "fastness" and their measuring means (tape measure, chronometer)	Qualitative correlation of d and t to "fastness" and the measuring means
Elaboration phase	T3/ST3a	
	Measurements, data collection, and tabulation of d, t, and "fastness" values upon pre-programmed motion trials of RC	Measurements, collection, and tabulation of data of d, t, and "fastness"
	T3/ST3b	
	Realization of the way that "fastness" can be measured	Realization of calculation of u ($u = d/t$) through pattern recognition from tabulated data
	T3/ST3c	
	Naming "fastness" as *speed*	Use of scientific terminology for u
	T4	
	Realization of d, t, and u as variables	Realization of the variability of d, t, and u and use of scientific terminology
	T5/ST5a	
	Definition of u	Scientific modeling of u through inferential thinking
	T5/ST5b	
	Interpretation of u	Scientific modeling of u through inferential thinking
	T6	
	Calculation and display of u through RC programming by the students	Implementation of the acquired knowledge about u calculation

in other contexts, i.e., the students were asked to find out through a display of video what was the u of Usain Bolt (running 100 m in 9.58 s in Berlin, 2009).

The implementation of all the LIs was scaffolded by the first author who provided support if needed, as far as understanding the expected outcomes of the Ts/STs worksheets was concerned.

4.2 Collection and Microgenetic Analysis of Data

Pretest/posttest and clinical interviews (Ginsburg 1997) were carried out at the macro-level that revealed evidence of conceptual change concerning *u*, yet varying among the students. This finding challenged even further the microgenetic analysis approach. In particular, in this chapter, an excerpt from the whole microgenetic analysis that concerns the elaboration phase, i.e., LI3 (T3–T6), is used to illustrate instances of the five dimensions of the microgenetic approach that were detected. Data were collected by means of video recordings, worksheets per T/ST, post-LI3 test (meso-level), and the authors' notes and were analyzed by a qualitative microgenetic approach that was conducted by the authors.

In particular, concerning the detection of possible conceptual changes and their dimensions, the cognitive activity of each student as it was made explicit in the discourse in the collaborative sessions, along with the filled-in worksheets, his written reflections, and the authors' notes, was reconstructed by the authors. More specifically, an iterative, detailed thematic analysis (Bryman 2016) upon dense data sampling from the aforementioned sources was carried out by the authors. Coding of the data was performed on phrases referring to the concepts *d*, *t*, and *u*, and their aggregation resulted in themes referring to strategies of thinking per T/ST. In this regard, static intervals were detected with no change in the way of thinking (same strategy) and periods of conceptual change (move to a new strategy). The video recordings allowed the verification of this reconstruction as it offered a continuum of data for reference so as to safely represent the process of change instead of using snapshots of it. In this way, the static intervals were detected upon which inferencing of conceptual changes was secured. Furthermore, the characterization of each change, as compared to the previous one, was possible as either positive or negative, i.e., getting closer or diverging from the scientific definition of *u*, respectively.

As far as the detection of ER function as mindtool is concerned, a grounded theory analysis (Bryman 2016) approach was followed upon the aforementioned data. More specifically, all the ways of interacting (physically/mentally) with the RC, as was made explicit by each student in all the aforementioned data, were detected and coded throughout the Ts/STs. This grounded theory procedure was a back-and-forth procedure along with thematic analysis, as coding was informed by both the data and the theoretical background of ER as mindtool. The aggregation of the codes at a higher level of abstraction resulted in attributes of the ER use as mindtool.

Finally, a discourse analysis (Bryman 2016) was also performed on sampled transcripts of the collaborative sessions where the RC was used. In particular, the aim of this analysis was to reveal the contribution of the RC to conversing (indicative examples can be found in Kazantzis and Hadjileontiadou 2018).

4.3 Results

In Fig. 2, a Q-COREA microgenetic analysis of data from LI3 (T3–T6) (total time span 90′) accompanied with four exploratory memos is presented.

In particular, the upper part of the Q-COREA depicts the expected performance, according to the learning design per Ts/ST, as it is denoted in brackets by the scientifically sound thinking strategies concerning *d*, *t*, and *u* (see also Memo 1).

Below the upper part, the Q-COREA depicts the results from the microgenetic analysis at three layers. More specifically, a stack of dyads of lines per student/group represents the first two layers of analysis, which were dedicated to the conceptual change. More specifically, the first line of the dyad depicts the reconstructed student's thinking strategies per T/ST and across the LI3 (see also Memo 1). In the second line of the dyad, the static intervals are presented along with the characterization of the cognitive transitions (positive or negative) based on the comparison of the reconstructed to the expected thinking strategy (see also Memo 2). Moreover, along with the stack of dyads, the mode of work (individual or collaborative) is denoted (see Memo 3). Finally, the third layer depicts the attributes

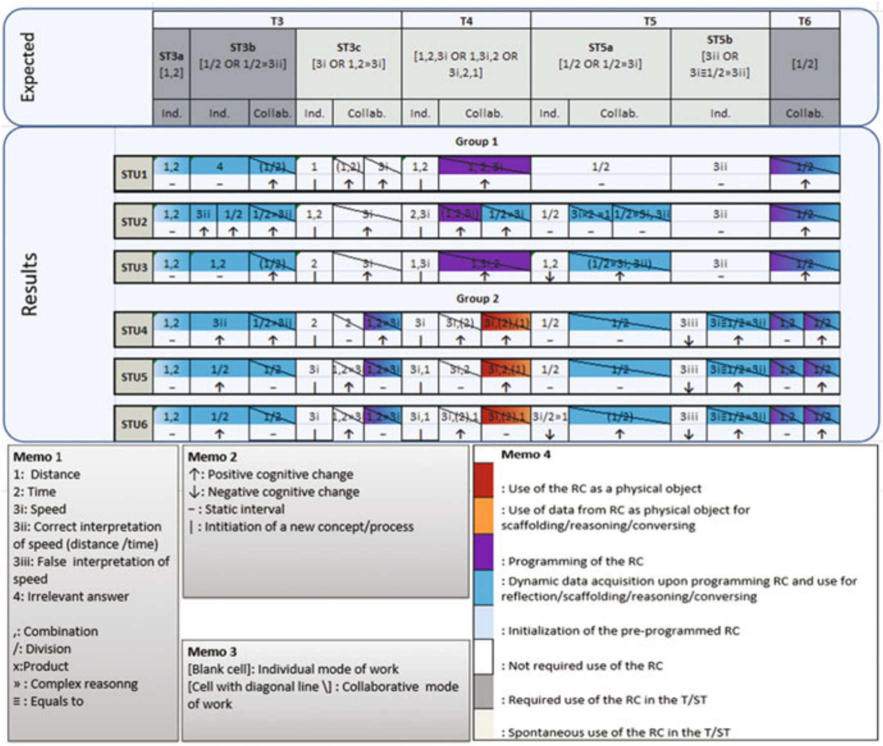

Fig. 2 A Q-COREA of the LI3 (T3–T6) results in the speed case study

of the RC use as mindtool by means of their different coloring (see Memo 4), along with Ts/STs, either as required or spontaneous use (see Memo 4).

The results from the discourse analysis (Bryman 2016) revealed that the RC triggered (a) discussions and negotiations upon the students' ideas for the interpretation of the data acquired by it (e.g., ST3b and ST5a/both groups, T4/group 1); (b) justification of reasoning, provision of proof, and persuasion efforts towards other members of the group upon RC testing (e.g., ST3c and ST5b/group 2, ST5a, and T6/both groups); and (c) resolution of cognitive conflicts by RC scaffoldings and proof by performance which leads to a commonly accepted finding (e.g., T4/both groups). The results of this analysis were not depicted in Fig. 2, due to its dense microgenetic character that was needed to detect the diffusion of the above findings as opposed to the aggregated qualitative character of Q-COREA.

4.4 Discussion

The speed case study offered a paradigm of the materialization of the modules of the ERMA (see Fig. 1).

4.4.1 Robust LI Design Decisions to Embed ER, Provoke Conceptual Change, and Produce Rich Data

Concerning the design of the ER tasks (Mikropoulos and Bellou 2013), the RC was used as a paradigm with strait analogy to a familiar authentic object, and the Ts/STs were materialized through a series of six worksheets. In particular, the design of these worksheets followed a specific goal-oriented cognitive processing (intuitive to qualitative correlation and finally to quantitative correlation of the kinematic concepts and the scientific modeling of speed) (Pakdaman-Savoji et al. 2019) (see also Table 1). Actually, the designed worksheets were a combination of "doing to meet thinking challenges in the Ts/STs," of "making reflections explicit by writing them," and of "making conversing results explicit by collaborating on writing a text as a common outcome" while working upon different concepts, d, t, and u, in both modes of work. This design reinforced the ER function as mindtool since it increased the possibilities for active participation (learning by doing), cognitive scaffolding, reflecting, and conversing through different forms of discourse (for reasoning, proving, debating, persuading, negotiating, etc.) (Jonassen 2000). The outputs of these worksheets served as probes upon which the conceptual change was assessed. While working with the Ts/STs, the students were free to unfold their own strategies. In this way, a variety of Ts/STs was used including different probes, yet all upon a common structural basis, i.e., the d, t, and u variables (see also Table 1). In this way, the common structural basis contributed to the realization of the thinking strategies of the students about the u, yet their nonidentical type provided differentiating sequences of probes that helped the transfer of learning to novel contexts. In this way, a balanced approach to the problem of the use of repeated measures in the microgenetic analysis was avoided (Brock and Taber 2017) and provided the opportunity to detect more interesting information in the empirical data. According to the RC as mindtool (Pakdaman-Savoji et al. 2019), learning design of Ts/STs foresaw opportunities for frequent, required, or spontaneous physical and mental interactivity among students and it (see also Fig. 2, Memo 4) and distribution of cognition through the execution and measurement accuracy of kinematic concepts from the RC in the role of cognitive partner (Jonassen 2000). The T3 which constitutes the main activity of the LI3 is a characteristic paradigm of the labor division between the learners and the RC. On the one hand, the RC precisely performed different linear motions by calculating and displaying each time its speed on its screen, whereas on the other the students had to deal with deeper cognitive processing of the extracted data, organizing, recognizing, and judging emerging patterns concerning the way speed was calculated by RC. Finally, the preparatory LIs (LI1/LI2) and Ts of LI3 (T1/T2) created opportunities for elaborating on existing knowledge, prior to the main elaboration phase of LI3 (T3–T6) (see also Table 1).

4.4.2 Detection of Possible Conceptual Changes and Their Dimensions

The microgenetic analysis (see Fig. 1) of the elaboration phase (T3–T6) was conducted upon sampling of data that were collected by multiple sources. The sampling procedure was decided after iterative acquaintance with them, so as to capture the static intervals and sufficient conceptual efforts that denote conceptual change (Brock and Taber 2017). As opposed to existing tools (e.g., CORDTRA), a Q-COREA graphical representation of the microgenetic analysis was proposed which is grounded on the microgenetic analysis results that run at the background, but depicts a more abstract representation that brings at the front the core information. Thus, Q-COREA is a kind of compressing the data, yet without minimizing the microgenetic analysis procedure, a core issue that differentiates it from other approaches of point sampling. Based on the aforementioned analysis, dimensions of the detected changes were also revealed (Siegler 2006) (see also Fig. 2), i.e., the source of change (stemming from the LI design considerations), the path of change (through sequences of static intervals and positive/negative cognitive trials), the variability of change (different individual/group strategies between static intervals, as depicted in Q-COREA), and the breadth of change (uptake towards the transfer of the scientific notion of the u concept to the Usain Bolt problem that was posed as posttest after T6). Future longitudinal research work might reveal the stability of the realization of the concept of u at its asymptotic level (rate of change).

4.4.3 Detection of ER Function as Mindtool

Through the microgenetic approach, attributes of the RC use were made explicit (see Fig. 2, Memo 4). Upon the learning design, the use of the RC was expected only in T1, ST3a, ST3b, and T6 (see Table 1 and Fig. 2). It may be argued that this design put some limitations concerning the function and use of the RC, yet it highlights the open character of the LI. For evidence of the above, the students, being experienced in the ER programming, initiated spontaneously the use of the RC in the rest of the activities (ST3c/T4/T5) (see Fig. 2, Memo 4). It is interesting that the RC was felt indeed as a learning companion (Mikropoulos and Bellou 2013) in the collaborative sessions in combination with the rich discourse that was developed. The qualitative representation of Q-COREA allows for the depiction of the transition between attributes of the RC use that were revealed through the microgenetic approach. All of them support its function as mindtool (Mikropoulos and Bellou 2013; Eteokleous 2019) (see Fig. 2, Memo 4), yet delving deeper into the notion through a variety of different attributes. This fine-grained approach of ERMA gets away from the pre-/post-assessments that consider a uniform function of the ER as mindtool.

The speed case study revealed the potentiality of the ERMA robust design of LIs in order to embed ER as mindtool in a learning context. This design supports the production of rich data from the learning context for the microgenetic analysis that follows. Moreover, the proposed Q-COREA contributes to the representation and easier interpretation of the results. However, the ERMA approach entails laborious procedures during design and analysis.

The findings from this small-scale case study cannot be generalized but can be informative for potential other learning contexts. Towards this direction, measures of validity and reliability were considered (Brock and Taber 2017). In particular, concerning the validity, a variety of Ts/STs probes was used, and the theoretical basis and data types of the ERMA approach were presented. Finally, concerning the reliability, a detailed description of the procedures and methods was provided.

5 Conclusions

The chapter is challenged by the lack of extended research work in the area of the microgenetic analysis of ER use as mindtool. A case study is used to successfully materialize the ERMA microgenetic analysis along with the Q-COREA graphical representation of its results. The chapter proposes the microgenetic approach as a more fine-grained and robust analysis that can manifest, in the context of interest, possible areas and ways that ER can contribute to learning. To probe further, an ongoing microgenetic analysis of the data of the same case study focuses on each detected attribute of the RC use in relation to the conceptual change that it provoked. Such work is expected to donate to research work towards deeper realization of the contribution of ER as a mindtool in learning settings.

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Bringing Informal E-Learning into the School English as a Second Language Classroom: What Do E-Sports Do to Learning?

Hampus Holm, Etienne Skein, and Kirk P. H. Sullivan

1 Introduction

Today learners' literacies are digital and ubiquitous and include contexts such as e-sports, computer games, Netflix parties, and messaging. Their ubiquity also means digital literacies have gained a central place in out-of-school activities, and these forms of ICT-based literacies provide informal learning opportunities to complement those provided in formal schooling. We use "e-sport" in our title as a metaphor for all out-of-school ICT-based literacies while at the same time highlighting the importance of e-sport for students aiming for the elite, in much the same way as others aim for the elite of traditional sports such as football, skiing, and swimming.

Coupled with the shift toward digital and ubiquitous literacies is a shift to communicating in English in parallel with first language(s). National and regional linguistic boundaries no longer define the linguistic repertoire individuals encounter and use to communicate in their leisure time. Indeed, English is used out of school and is an integral element of school-aged students' informal e-learning experiences. ICT potentially enhances the learning of English as a second language (ESL). This chapter presents questionnaire data examining the out-of-school ESL literacies of upper secondary school students in Sweden and discusses how these activities support informal and formal language learning. In order to ensure informal e-learning of English engages with formal classroom English language learning and

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assessment, teachers need to know about and understand the significance of the informal e-learning opportunities and practices.

Alvermann (2018) captured the disconnection between popular culture and what happens in school and wrote: "the work of students who self-identify as users and producers of popular culture is rarely visible to their teachers" (p. 188). As popular culture has increasingly moved into digital worlds with synchronous written (and spoken) interaction, understanding how school students understand the impact of ICT with its material conditions and potential for out-of-school informal learning practices and connect these to their school experience has grown in importance.

Crossover between what school students do in their leisure time and in school is happening. However, this crossover tends to move the literacy of school into the ICT platforms and arena used by students in their leisure time, rather than the literacies of leisure time moving into school. For example, Facebook is used in many educational contexts (see, for example, Aydin 2012; Ventura and Quero 2013; and Wang et al. 2015) and is used to support language learning (see, for example, Aydin 2014; Börekci and Aydin 2020; and Kabilan et al. 2010).

Although students report positive experiences of using Facebook as a means to share information and hold discussions, how this differs in terms of literacy from those of teaching and learning platforms such as Moodle, Sakai, Canvas, and Google classrooms is not obvious. Further, with teachers monitoring and grading discussions in these platforms, the discourses of school become dominant. Hence, the moving of school discourses to Facebook groups has not ameliorated the disconnection Alvermann (2018) captured.

In the *Rise of Writing: Redefining Mass Literacy*, Debra Brandt (2015) wrote: "As illiteracy slid into stigma, the inability to read became increasingly punishing. Instead of being accommodated, illiterate people had to accommodate to the risks of living in a reading world" (p. 135). Everyone is writing daily. Yet, what is illiterate stigma among school students is no longer the individual who cannot write sufficiently academically to pass a school examination in their first language. It is now the individual who is unable to negotiate the social digital media literacy landscape who is 'punished'. And in countries where English is neither the societally ambient language nor the language of school, this also means being able to do this in ESL.

E-sport, widely described as competitive gaming (Reitman et al. 2020), has grown in popularity over the past decade and is a part of the ICT landscape that requires ESL for non-native speakers of English. Reitman et al. (2020) pointed out that "competitions can be held between amateurs and professionals, in a garage between friends or in a stadium between world-class teams" (p. 40) with "communication within a team or between competing teams [...] possible or enhanced because of the mediating technology" (p. 40). E-sports are played on platforms such as Xbox, PlayStation, and PCs, and the computer games include Rocket League, Counter-Strike: Global Offensive (CS: GO), DOTA 2, World of Warcraft, and League of Legends. These are played by high school students, much in the same way high school students play other sports, such as football, hockey, netball, and rugby union, with some school students aiming to compete at regional, national, and international level.

One example of a major international e-sport competition is *The International*, the annual DOTA tournament where the top 16 teams in the world compete. The forms of within and between team communication are the same for informal local and formal international e-sport competitions—the players talk and send within platform typed messages. As most games are written in English, English tends to be the dominant language of within-game communication.

Rambusch (2010) pointed out inexperienced players use Internet fora "to discuss the game with other (more experienced) players" (Rambusch 2010, 112). Although there are national fora such as the Swedish forum Fragbite (https://fragbite.se/), international fora, such as Esports.net (https://www.esports.net/), require English literacies.

Multiliteracies (Cope and Kalantzis 2009) are key and important skills for e-sports. Novice players, such as high school students, grasp this aspect quickly by playing with others and through learning about the game in a community of practice. E-sport, both informal and formal, has the potential to hone players' ESL multiliteracies, yet in ways that diverge from those of the ESL classroom. Rambusch (2010) wrote:

> advanced players find individual skills, such as fast reflexes and excellent hand-eye coordination, quite overrated in comparison to other skills they need: the ability to communicate well as members of a team, to grasp the finest details of the game, and to adapt to the opposing team's strategies and moves. As two players pointed out, "understanding of the game is more important than a good aim" and "a smart team wins over a team that aims better." (p. 111)

This highlights the centrality of communication and the multiliteracies necessary for success. To learn these literacies, novice players play with, watch, and communicate with more experienced and successful players and teams. This discussion and learning between players from different countries invariably happens in English and thus not only improves their e-sport skills but also develops their ESL literacies.

In sum, it is thus apparent that today's school students use their phones, computers, and gaming consoles to read texts, arrange meetings, discuss complex social challenges, and participate in Netflix parties, computer games, and e-sport by communicating in written and oral conversations. Or as Jacquet and Lindqvist (2020) wrote: "Ungdomars literacypraktiker handlar således mer om att delta, skapa och agera genom multimodala texter, än att tyda bokstäver i löpskrift på räta rader" (p. 144) [Adolescent literacy practices are thus more about participating, creating and acting through multimodal texts, than interpreting letters in running text in straight lines, authors' translation]. All these ICT activities are cognitively demanding and include literacies that are not accepted for achieving high grades in school, where academic writing styles are preferred. Moreover, these ICT literacies are infrequently used to support learning of the academic writing discourse.

Much recent research has focused on bringing ICT literacies into the first language classroom. For example, recent intervention studies include the one by Jacquet and Lindqvist (2020) who introduced transmedia gaming into the Swedish first language classroom as a way to engage the students in literacies. The school students were able to use the chat functions in the game to write text messages to communicate interactively with other students in the game. This study focused on engagement with the task without directly linking the intervention to national grading criteria. The intervention, however, provided the opportunity for meta-discussion of narrative ideas and was particularly successful in engaging the students familiar with the world of gaming and digital play. Another example of a recent intervention study is the one by Svensson and Haglind (2020). They worked with merging the text- and ICT-based media format students encounter out of school with the text- and ICT-based media formats students encounter in their first language literature classrooms. The students enjoyed the intervention and its use of creative learning that provided the possibility to recreate, change, and develop stories in various ICT-based media. However, the teachers, who serve as gatekeepers to technological change in schools, felt the intervention challenged the traditions of first language Swedish teaching too much.

Neither of the above examples considers how the students themselves see a link between the material conditions for learning created by out-of-school ICT-based literacy practices afforded by activities, such as e-sports, computer gaming, Netflix parties, and messaging, and what their school teachers value when grading their written work. Through an interview study, Holm and Sullivan (2021) examined how upper secondary students felt their teachers valued (and graded) these literacies when grading written examination tasks. They reported that for first language learning, the out-of-school literacy practices of the majority of school students do not align with how the students' experience their teachers' requirements for high course grades. That is, the ways of writing in informal digital literacy contexts differed substantially from those required by formal schooling. Given that the material conditions of these ICT-based literacies encourage the use of English, for example, to communicate with friends from other countries and to join e-sport games that involve participants from many countries, it becomes interesting to investigate the informal e-learning of ESL through ICT-based English language literacies.

Little research has focused on informal e-learning of ESL. Much research as summarized by Reinhardt (2017) has aimed to exploit digital gaming in ESL teaching and learning situations. For example, Ranalli (2008) considered how the Sims, together with bespoke additional material, could be used in university-level ESL teaching. Other research has focused on teacher and pre-service teacher attitudes toward and beliefs about ICT-based game-based language learning, for example, Blume (2020) considered the views of 150 teacher education students at Leuphana University in Lüneberg, Germany. She found that these future teachers did not engage much with digital games, but had positive beliefs regarding the potential of digital games for supporting language learning. Research that has specifically considered informal ESL e-learning in the area of digital gaming has reported positive effects (Sundqvist 2009; Sylvén and Sundqvist 2012). Sundqvist (2009) found a positive correlation between the time spent playing digital games and ESL proficiency. 15–16-year-old school students who gamed the most had the best vocabulary scores, and the male students in her study outperformed the female students. Sylvén and Sundqvist (2012) ran tests of ESL reading and listening comprehension and vocabulary on 11–12-year-old school students and again found that ESL proficiency, as measured by these tests, correlated with time spent playing digital games.

Given this previous research, we decided to investigate how informal e-learning of ESL through ICT-based English language literacies plays out when school students take an authentic examination, the Swedish National Test in English, and to investigate the students' voice. Specifically, we ask the following research questions:

1. What is the correlation between ICT-based literacy practices that informally support the learning of ESL and the value the teachers place on what is learnt informally as evidenced in national test grades in the school subject English?
2. Do school students see any transfer between their ICT-based literacy practices that informally support their learning of ESL and their school work in ESL?

As the Swedish ESL syllabi are communication-based and less focused on a range of traditionally academic written genre (Gy 2011), we hypothesis that informal e-learning of ESL will support grade achievement in the ESL class in high school. English has high status due to its function in ICT-based activities such as e-sports, and this will encourage students to see English as a useful school subject. A counterhypothesis is that this growing base of informal e-learning by high school students undermines the academic learning of English and results in an English competence with a limited vocabulary and an uncertainty in the usage of words; this would align with the work of Hincks (2005). However, other research on the impact of out-of-school computer gaming (Sundqvist 2009; Sylvén and Sundqvist 2012) as outlined above, however, suggests this is unlikely.

2 Method

The context for our study is Sweden that is a technically advanced country where nearly everyone has continuous access to stable fast Internet. Indeed, mobile data access is near universal. Further, most secondary and upper secondary schools provide personal laptops for their students, and that can be taken home. Of note is that in Sweden, 12–18-year-olds report that activities such as Netflix parties, games, e-sport, and other ICT-based activities were their top priority leisure activities and that 99% of grade 4 primary school students report owning a personal smartphone (Swedish Media Council 2019).

2.1 Participants

2.1.1 Questionnaire 1

Questionnaire 1 data was collected from 71 first year upper secondary school students (59 male and 12 female) from 5 classes in 3 schools in northern Sweden. All participants were taking English as a school subject and the course *English 5*; this is a compulsory upper secondary school course in Sweden. The students reflected the full range of the student population and subject combinations. Their ages ranged from 17 to 20 years (83.1% were 17 years old). Two of the schools were located in rural areas, with populations below 10,000, and 1 school was located in a city with a population above 100,000.

2.1.2 Questionnaire 2

Questionnaire 2 data was collected from 39 first year upper secondary school students (33 male and 6 female) from 3 classes from 1 school located in a city with a population above 100,000 in northern Sweden. Again the students reflected the student population and the range of possible subject combinations. Their ages ranged from 16 to 20 years (79.5% of the students were 17 years old).

2.2 Materials

The materials consisted of two questionnaires and Swedish National Test results. The questionnaires were piloted with two upper secondary school students who commented on the appropriateness of the questions and discussed the questions researchers not involved in the project. The result of the piloting was that the questions were more explicit regarding the ICT-based media about which we were asking questions.

2.2.1 Questionnaire 1

The questionnaire consisted of 26 questions and was part of a larger study, so not all the questions are relevant to the present study. The first question required the student to confirm that they had understood the instructions, and the second question required them to enter their personal code. In this way their personal information was not directly connected with their answers. Then other demographic data was collected: gender, age, area of study (in Sweden, courses are linked into named areas of study), and parental level of education. In this first block of questions, the participants were also asked if they preferred to write in Swedish, English, or another language.

The next block asked questions relating to ICT media use. The questionnaire asked for the frequency of use of nine media technologies found in the Swedish Media Council's recurring survey about Swedish adolescents' media habits (Swedish Media Council 2019): books, tablets, magazines/newspapers, computers, smartphones, TV, radio, mobile gaming consoles, stationary gaming consoles, and the Internet. ICT-based media technology use was not specified by domain because of the mobility of most of the technologies and the borderless literacies they enable (Burnett and Merchant 2015). The questions took the form of (i) how often do you use X, (ii) why do you use X, (iii) which three X do you use/watch/visit most, and (iv) which three X did you read last? The last two question forms allowed us to investigate the literacy affordances of a range of technologies.

The next question of relevance to the present study asked how the participant thought their ICT-based media usage helped their school grade in English or not. Then to gain an impression of that day's literacy activities, we asked the participants to list the last three things they wrote and where they wrote them, as in using ICT-based media or otherwise. And then how much time they did various things during the day to be able to place their answers in a social context.

Five items on school writing self-efficacy were then presented to the participants, first relating to Swedish and then to English. Only the responses relating to English are of relevance to the present study. The questions were selected from the 16-item Self-Efficacy for Writing Scale Test (Bruning et al. 2013). The participants were asked to rate their self-efficacy relating to the following five questions from 1 (I do not agree at all) to 4 (I totally agree):

1. I enjoy writing assignments in the subject English in school.
2. I find writing assignments in the subject English in school hard.
3. I am good at writing assignments in the subject English in school.
4. I find it easy to come up with ideas when doing writing assignments in the subject English in school.
5. I make an effort to finish writing assignments in the subject English in school.

The final three questions providing data for the present study asked how often the participants wrote texts longer than 100 words, their school grade in English, and the school grade they were aiming for during the current school year. The final questions asked for consent that had been given orally before the questionnaire to be confirmed on the questionnaire—a school student could have changed their mind during the questionnaire, and this provided them with a simple way to opt out without creating an event that they might find embarrassing in the classroom—and a question asking if we could access their national test results or not.

2.2.2 Questionnaire 2

The questionnaire consisted of 18 questions. Here we focus on the general questions and the ones relating to English. This questionnaire focused on writing practices. The first section collected the same demographic information as Questionnaire 1.

Again the questionnaire is part of a larger study. The questions relating to English asked: How often do you read texts longer than 200 words in English, and where, for example, on social media and in computer games? How often do you write texts longer than 200 words in English, and where, for example, on social media and in computer games? And finally two questions asked about how various ICT-based media support the writing of argumentative texts in school and in what ways.

2.2.3 Swedish National Test Results

In Sweden, national testing, as in many countries, influences the national academic discourse and the teaching and grading in schools. English is one of the subjects tested, and the local results are used nationally for school and regional comparison and to assure educational equity, not least for final school grades. Locally, teachers are encouraged to use the test as a guideline for interpreting national course criteria and as support when grading their students (Projektet Nationella prov i främmande språk 2016). Test results are a strong indication of participants' academic English proficiency in relation to syllabus outcomes and grading criteria. One component of the national test in English is a writing task. This is written in the classroom and on computer and under supervision of a teacher. The test lasts for 80 minutes and no help can be offered to the students. The task is to write a short descriptive or argumentative text on set topics. The test is graded with A–F, and the grading teachers receive strict guidelines and text examples for each grade level. The focus is on genre and writing for specific readers more than language, in alignment with the curriculum goals outlined above. We collected the results of participating students who agreed to use their national test results.

2.3 Procedure

2.3.1 Questionnaires 1 and 2

The questionnaire data was collected in the classroom during lessons. After explaining the reasons for the research, informing the students that participation was voluntary and they could stop answering and withdraw at any point, the participants were directed to an online questionnaire. This facilitated easy collection of the data. During the data collection, the class teacher and the first author were present to help with any technical problems or answer questions to clarify the questions. The students took approximately 20 minutes to fill in the questionnaire.

3 Ethical Considerations

The Regional Ethical Review Board in Umeå, Sweden, was consulted about how to assure the study followed the requirements of the Swedish Law (Law 2003:460 Act concerning the Ethical Review of Research Involving Humans). They advised that no formal application was necessary. As all participants were 15 or older, Swedish law requires no parental consent after the age of 14. The participants were informed about the project, its aims, and its risks in writing and orally. The participants were able to ask questions about the project before deciding whether to consent to participate in the project. Separate consent was collected for each part of the study. The participants were also informed that their answers would be coded and presented anonymously. All questions were answered using a code, and when names are used, these are not the names of the participants. The participants were also informed they could remove consent at any time and withdraw from the study and that we would not ask for a justification for their decision. Moreover, two separate check boxes were integrated in the questionnaire, asking for consent along with information on how to cancel participation. The Swedish Research Council's guidelines for handling data have been followed.

4 Analysis and Findings

The data collected via the questionnaires covers many areas. Here we focus only on the data related to our research aim of investigating how informal e-learning of ESL through ICT-based English language literacies plays out when school students take an authentic examination, the Swedish National Test in English. Or as we framed it in this paper's title, *what do e-sports do to learning and assessment?*

We used the data provided in Questionnaire 1 to answer our first research question: What is the correlation between ICT-based literacy practices that informally support the learning of ESL and the value the teachers place on what is learned informally as evidenced in national test grades in the school subject English?

The 71 upper secondary school participants reported the use of 400 media. These we coded for affordances for literacy and transformed these into variables for use in the analysis. This transformation to a few broad categories allowed us to overview when and how ICT-based media may affect English language learning and assessment. The categories are writing, reading, and language. We defined the categories and transformed the data in the following ways.

Writing is defined as orthographic writing using letters in any medium. This category ranges from 0 to 3 and aims to capture the level of writing that the media affords: 0 means that the user cannot produce any written text at all, 1 that at maximum a couple of sentences can be produced, 2 that a short instructional text of less than a 100 words can be written, and 3 that longer texts can be produced. For example, books are coded as 0; many computer games, such as those without chat functions, are coded as 1 or 2; and social media and some websites, those we considered to encourage writing, are coded as 3.

Reading is defined as visible and understandable orthographic text consisting of letters, words, and utterances. This category ranges from 0 to 3 and aims to capture the level of writing that the media affords: 0 means that no reading is afforded, 1 that a short text consisting of one word up to a couple of sentences is afforded, 2 that a short instructional text of less than 100 words is afforded, and 3 that a longer text is afforded. Social media is categorized as level 3 as inclusion of and links to articles and other longer texts, such as e-books, magazines, and other discussion fora. Some games, for example, World of Warcraft, were coded as level 3 as elements of the game include longer texts. Games with only a title page or a single-word interface, for example, Tetris, are coded as 1.

The language used with each media, self-reported by the participants, was Swedish or English. If a medium afforded writing is coded as 3 and the language used was English, it was coded as writing in English 3, and if it is a medium that afforded writing in Swedish, it was coded as 0. Participants could also answer "other language," but this alternative was only reported a few times. We therefore decided not to include these responses in our analysis.

In Table 1, we present an example of one participant's media use and how each technology was coded for literacy affordances. This participant reported the use of many media, which results in a high exposure to literacy affordances. Interestingly, English writing in the ICT-based exposure to English occurs only on Facebook.

The group's mean affordances score for reading and writing, and hence language learning can be summarized as follows: reading in Swedish $\overline{x} = 10.7$ (sd = 6.0); writing in Swedish $\overline{x} = 4.9$ (sd = 2.5); reading in English $\overline{x} = 1.0$ (sd = 5.5); and writing in English $\overline{x} = 2.0$ (sd = 2.3). This confirms that contemporary upper secondary school students have access to and use ICT-based media that potentially support the informal learning of English and in ways that were not generally available 30 years ago.

4.1 Gender Difference, Self-Efficacy, and Literacy Affordances Interact with the English National Test Writing Task Grades

Using the questionnaire data and the participants' results on the writing assignment part of the national test in English, we ran an ordinal LOGIT regression with a 0.405 pseudo-R-Square Nagelkerke value in SPSS 25 with the national test results for English writing assignment as the dependent variable. The national test scores were recategorized from F–A to 1–6. The independent variables were self-efficacy for writing academic English and the sums of columns 3–6 in Table 1. The self-efficacy score is the average of the five self-efficacy question responses, resulting in a score between 1 and 4. The remaining four independent variables have a maximum

Table 1 Example of one participant's media use and how they were coded for literacy affordances

		Affordances for			
Participant's response	Media category	Reading Swedish	Reading English	Writing Swedish	Writing English
2048	Computer game	0	0	0	0
Athena	Website	3	0	0	0
Community	Film	0	2	0	0
End of Days	Book	0	3	0	0
Facebook	Social media	2	2	2	2
Films	Film	0	2	0	0
Häst&Ryttare	Magazine	3	0	0	0
Hippson	Website	3	0	0	0
Illustrerad vetenskap	Magazine	3	0	0	0
Röta	Book	3	0	0	0
SchoolSoft	Website	3	0	3	0
South Park	Film	0	2	0	0
Tumblr	Social media	0	3	0	0

Table 2 Variables used in ordinal regression

Dependent variable	Results on the national EFL writing test (1–6, F–A)	
Independent variables	Gender Mean_Efficacy_ENG AffWriteENG AffWriteSWE AffReadENG AffReadSWE	Male or female (0/1) Self-efficacy for academic EFL writing (1–4) Affordances for writing English (0–54) Affordances for writing Swedish (0–54) Affordances for reading English (0–54) Affordances for reading Swedish (0–54)

Table 3 Results of the ordinal regression analysis with the results on the national test in English writing assignment as the dependent variable

Dependent variable: results on the national EFL writing test		
Independent variables	Parameter estimate	Significance (* $p = 0.05$)
Gender (male)	0.318	0.612
Gender (female)	0 (reference)	–
Mean_Efficacy_ENG	1.394	0.001*
Affordances for writing English	0.065	0.573
Affordances for writing Swedish	−0.352	0.001*
Affordances for reading English	0.011	0.830
Affordances for reading Swedish	0.129	0.011*

score of 54 and are based on columns 3–6 in Table 1. Each participant was invited to list three examples for six media that results in a maximum of 18 examples. Each example was coded 0–3 for reading, writing, and language as outlined above. Hence, 18 times 3 results in a maximum score 54 and a lowest score of 0. The ordinal regression variables are overviewed in Table 2, with the results presented in Table 3.

The results of the ordinal regression show that participants who used media that offered the possibility to read a lot in Swedish were more likely to get higher results on the English national test's writing assignment than participants who did not use media with this affordance. Interesting, participants using media that provided opportunities for writing in Swedish were more likely to get weaker test results on the English writing assignment (the parameter estimate is negative, −0.352). This would suggest that the skills the teachers grade in the writing task differ from the one's the students engage in and that having an awareness of these writing skills, even if not practiced in digital media, is more important than writing in the ways promoted by ICT-based media.

Turning to exposure to reading and writing in English, the ordinal regression analysis found no significant correlation between interaction with media that afford reading and writing in English and the grade awarded on the writing component of the national test in English. This is a puzzling result. The participants used ICT-based (and other) media that afford reading and writing in English, but this does not correlate with higher grades. One explanation might be as Alvermann (2018) posited, "popular culture is rarely visible to their teacher" (p. 188), and writing in

ICT-based media is perhaps invisible or kept out-of-the-school classroom and the grading process. That is, the informal e-learning does not inform formal assessment.

If we consider the results of the ordinal regression in relation to upper secondary school students' activities, other patterns of explanation emerge. First, we noted that participants who use a lot of media affording writing in Swedish are more likely to receive low test results. We would like to argue that this is not because of negative influence from social media or websites (the most common media forms for this affordance) but rather that these participants prioritize these activities over other activities, for example, reading fiction, that would more effectively support their academic writing.

Second, exposure to English reading and writing comes mainly from the use of computer games and websites. The literacies offered by these ICT-based media do not seem to be enough to offer any transfer effect for the user into the context of upper secondary school academic English writing. Either the amount of exposure is insufficient, or there is some other quality that these ICT-based media lack. However, third, alongside the significant relationships for literacy affordances for reading and writing in Swedish with English grades, the participants' self-efficacy demonstrated a strong positive relationship to the participants' results on the English writing test. Participants with lower self-efficacy were significantly more prone to achieving lower results than participants with higher self-efficacy. These results are in line with similar studies on self-efficacy for writing (e.g., Bruning and Kauffman 2015). Fourth, and very importantly, no statistical gender difference in the national test in English writing assignment results was found. At one level, this is not surprising as English is one of few school subjects where boys and girls achieve equally in Sweden. If we look at the national results for Spring 2019, we note that for school subject Swedish, the mean pass score for male students was 9.7 and for female students 11.7, and the mean score for male students failing was 5.9 and for female students 7.9. This represents a clear difference in performance. However, in English, we note that the mean pass score for male students was 12.0 and for female students 11.8, and the mean score for male students failing was 9.6 and for female students 9.9. This shows no difference in performance in English at the national level on the national test. That we found no statistical gender difference shows that our sample does not deviate from the national result in this regard. Thus, although our finding is not surprising, we need to ask what do boys do to achieve equally in the school subject English, where they do not in other modern language subjects or even in their first language, Swedish.

The answer to this question is uncovered in the questionnaire data when looking at the number of examples provided by boys to the questions: Which three computer/console/mobile games do you play most, and which social three social media sites do you use most? Both of these questions made it clear that there was no need to list three, if three were not frequently used. The male participants in our study answered more frequently than the female participants. This we interpret as the boys spending more time using these ICT-based media and most frequently in English too. Hence, although our ordinal regression model does not suggest a link between ICT-based uses of English, we argue that the lack of gender difference on the writing task in the English national test can be attributed to the boys' use of e-sports. This aligns with the findings of Sundqvist (2009) and Sylvén and Sundqvist (2012) and extends the findings to an authentic school task with a more complex set of proficiencies than knowledge of vocabulary.

The teachers may not be aware of what the boys are doing out of school, but it lifts their English performance to the same level as the girls. Perhaps these out-of-school informal e-learning opportunities lift the status of English within their peer groups strengthening the importance of being seen to do well in the school subject English.

In sum, the answer to our first research question is that ICT-based (and other) reading in Swedish affects writing performance in English positively but that ICT-based writing in Swedish has a negative impact on English writing as evidenced by national test grade. We also found that ICT-based (and other) reading and writing in English have no impact on writing in English as evidenced by national test grade. However, the lack of gender difference suggests that online activities in English create more equal outcomes as evidenced by grade in English writing. Thus, for boys, ICT-based literacy practices do informally support the learning of English.

4.2 Students' Perception of the Impact of ICT-Based Literacy Practices on Learning to Write in English

We used the data provided in Questionnaire 2 to answer our second research question: Do school students see any transfer between their ICT-based literacy practices that informally support the learning of English and their school work in English?

In Questionnaire 2, the participants were explicitly asked which of the following do you believe have helped you write better argumentative texts in English. Social media texts and blog posts were considered by 28 participants to have positively contributed to their argumentative English writing; nonfiction book and webpages, including Wikipedia, by 29 participants; fiction, including online texts, by 17 participants; daily newspapers and magazines, including online versions, by 23 participants; comics and manga by 13 participants; and computer games by 27 participants. Here we see that the students' view computer games and social media as important to their learning of English for writing argumentative text as the traditional forms of nonfiction book (and today webpages such as Wikipedia).

The participants were also asked to justify their opinions by writing a free text answer that explained in what ways these media supported, or otherwise, their learning of English for writing argumentative texts. Many justifications were left blank or very general. For example, one participant wrote "I see many argumentative texts on these platforms" without going into more details about which platforms. We can interpret platforms as meaning ICT-based platforms. Other participants were also general in regard to the help they have gained from ICT-based platforms.

For example, one participant claimed that they had learned all their English from computer games ("I have learned English almost from just computer games"), and another reflects that the time they spend online means that they get help or learn informally ("Computer games and social media help us most because we sit using social media in principle all the time"). In this way this participant added value to computer games and social media over other ways of learning English. Three further participants developed this idea in more depth. The first wrote, "I often play computer games that are almost always in English which really helped me with English throughout my childhood. I often read Wikipedia in English and Swedish and social media I use daily and see English words there daily." Here the participant has nuanced their use of gaming over time and that "seeing" English daily is useful to writing in English. The second reflects on confidence and the limitations of learning English via computer gaming, "I think that computer games make you feel more confident when writing texts in English. This also helps to make the texts better. However, I do not think that e.g. grammar gets better by playing computer games." This participant is able to distinguish between English for communication and correct grammatical and lexical form. The third reflects on how different media contribute differently, "Social media helps to form opinions and to learn how to argue. Fiction and nonfiction books help most with the language. Computer gaming develops my writing." Here we see an upper secondary school student who uses social media to understand how arguments can be constructed and how these influence people's opinions and that this can help them write an argumentative text in the English classroom. They also see that longer texts, such as (e)-books, can help develop language competences, while computer gaming helps with writing in English as games require that the players use the keyboard to write for communication with each other as we pointed out above in our overview of e-sport.

In sum, the answer to our second research question is that it is apparent that upper secondary school students value the transfer between their ICT-based literacy practices that informally support the learning of English and their school work in English. They value computer gaming and social media as highly as reading fiction books for the development of their language and argumentation skills. The free text justifications for these views show that some students are able to articulate the value of computer gaming and e-sport to the development of their English during their growing-up and to their writing, even if the skills learnt may not support formal aspects of English academic writing.

5 Conclusion

So what do e-sports do to language learning? Or more generally what does ICT-based informal learning of ESL bring to the upper secondary classroom and writing proficiency. Our results show that upper secondary high school students develop their English language skills via their informal e-learning and that this is rewarded in school with higher grades in English. Hence, this is not reflected in our ordinal regression analysis. However, as this ordinal regression also found no gender effect in the students writing in English, we argue that informal e-learning, including e-sports, lifts the boys' language and writing skills to the same level as the girls. The informal e-learning provides the high school students with English literacies that their teachers grade highly. In sum, it is clear that informal e-learning of ESL is an effective and useful tool for teachers to integrate into classroom teaching to improve the standard of English achieved in high school in the future.

However, if as Alvermann (2018) wrote this "is rarely visible to their teachers" (p. 188), how might the materiality of ICT-based literacies connect to school experience more explicitly and form part of the teachers' classroom repertoires? The types of studies conducted by Jacquet and Lindqvist (2020) and Svensson and Haglind (2020) are useful as an initial stage in such a process. Yet one in which the distinction between formal and informal learning was rubbed out and boundary between the language classroom and out-of-school activities in English was weaker would allow e-learning of English through e-sport and social media to strengthen the academic discipline of English. We suggest future research considers younger learners, not least as one participant in this study referred to using gaming and social media as part of his growing up with English. We also suggest that a more detailed interview-based study with students from the first year of school to the final year of school would help generate ideas how to erase the boundary between formal schooling and e-sport for ESL learning. Research that links recordings of authentic e-sport talk and written literacies would also be useful for confirming that the literacies the school students report occur. These recordings may show the use of oral and written translanguaging (García and Wei 2014; Williams 1994). How these may be used in the classroom is discussed by Skein et al. (2020).

As a final note, it is important to remember that Sweden is an advanced country with ubiquitous and fast Internet access. This study needs to be read with this in mind. It would therefore also be interesting to replicate this study in countries and areas where it cannot be assumed that upper secondary school students have fast continuous ubiquitous Internet access.

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Impact Assessment and Retention Rate of MOOCs for Supporting Dual Career of Athletes

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1 Introduction

In the last 30 years, there has been an increase of professionalism in sports and with this, the interest in the scientific approach to training and recovery of elite athletes has increased (Kellmann et al. 2018). The elite sports organizations such as championship teams and sports federation teams mainly aim at high performance in the competition (Mayer and Thiel 2018). The situations for high performance have changed spectacularly. Athletes need to give more time to training and competition and continue to respond to some limitations such as studying, spending time with their family or friends and having a quality of life (Burlot et al. 2018). Athletes' workload has increased reaching full-time occupation including training hours, competition, travel time and study requirements. Depending on the type of sport, elite sports career may last 5 to 10 years (Alfermann and Stambulova 2007). In this vein, athletes aiming to better prepare for future employment have to keep a balance between their studies and their sports career (Aquilina 2013). Most studies about athletic career, examined career development, professional transitions, and especially the retirement after sports career (Stambulova et al. 2009, 2020). Current research reveals the need for a holistic approach, highlighting that athletes have to deal with several transitions in sport, their studies and their psycho-social development (Debois et al. 2014; Wylleman and Lavallee 2004) and to reach this holistic approach the research in dual career for athletes is essential and represents a growing area of study (Condello et al. 2019; Aquilina and Henry 2010; Burnett 2010).

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The contemporary engagement between education and sports career has become a challenge for athletes. Furthermore, professional athletes often have to deal with transitions when changing homes, sports clubs, or sports arrangements. Physical Education and Sports faculties in Europe are only focusing on sports training and performance without the ability to offer flexible courses, predominantly through distance learning. Distance learning may offer to athletes the flexibility to organize the time and the location in order to cope with their athletic training and their academic obligations. Distance learning programs promoting the dual career of athletes, as have been organized and delivered in Europe, have not been convincing, as regards their quality, level, accessibility and their interactive character.

The dual career support services should be promoted among the community of athletes, coaches, sports federations or other stakeholders, specifically for athletes who trained outside the specific education and sports structures for talented and elite athletes. Athletes outside the choice of specific educational foundations and high-performance training centres are often uninformed of the existence of support programs. Supportive services may include: (i) Psychological assistance (personal development courses, career discovery, design, development and coaching, lifestyle management, skills to prepare and cope with transition and change, crises interventions (ii) Educational guidance and information and (iii) Employment guidance and information, preparation for a new work (EU Guidelines on Dual Careers of Athletes 2013).

The transition to the post-sport career is an inevitable part of the athletic career which combines both athletic and non-athletic context relevant to the new beginning after retirement from sports. The professional athlete's career has been finished by the age of 33 at means. For the more physically demanding sports, like gymnastics, the professional sports career lasts till the age of 18.5 years.

This paper presents the impact and the retention rate of six MOOCs to support dual career for athletes after a pilot evaluation. These MOOCs were implemented under the European Erasmus + Sport project entitled "Gamified and Online Activities for Learning to Support Dual Careers of Athletes" and acronym "GOAL." The chapter is structured as follows: The following paragraph is a brief description of the GOAL project. The third presents the needs analysis and development of the GOAL courses. The following presents the development of the GOAL platform. The fifth section presents the evaluation methodology and the results of this evaluation are presented in sixth section. The last section discusses the findings and presents the closing remarks and the steps of a future fulfilment.

2 GOAL Project

GOAL is a collaborative partnership project focused on the area of "EU guidelines on dual careers of athletes." The project aims to support active and non-active athletes in the development of their professional endeavours. GOAL identified and tested gamified learning and training activities to form best practices for supporting dual careers of athletes using digital technology such as games/gamification in sports.

More specifically, the project attempts to create awareness on dual careers by providing an enabling environment for addressing athletes' dual career incommensurable goals whilst leveraging athletes' skills and competencies (e.g. problem-solving, decision-making, communicating, teamwork and leadership) as means to help their integration in education, training and open labour market. GOAL creates a gamified online dual career educational programme for supporting dual careers of athletes using massive open online learning environments and games for sports, entrepreneurship and recreational activities. A set of interactive ICT-based tools offered to active and non-active athletes for acquiring skills and competencies necessary to consciously discover, plan and determine their future career goals once they complete their competitive sports career. Such skills are critical in developing athlete's continuous professional and life career development including efforts of coping with transition and change both as individual personalities being part of a wider community as well as professionals that will be following a career after sports competition, and thereby preparing them for a new job. The project effectively supports the start of dual careers embracing awareness of athletes to balance sport training and education and, at a later stage, sport training and employment. Psychological support through e-mentoring and e-coaching as part of support services was provided, aimed at helping athletes to overcome transitions in their careers inside and outside of sports. GOAL innovates by introducing games and gamification dual careers curriculum for helping athletes to conceptualise, plan and cope with the transition to education and open labour market. The project's outcomes have been implemented and evaluated in Greece, the UK, Cyprus, Portugal, Spain, and Poland.

More specifically, GOAL has implemented its goals in three phases: The first phase called "Need Analysis and Curriculum Development" has as the main goal to collect the needs of the users/athletes and their learning goals. Based on them to analyse their preferences and to develop the list of courses in a consistent curriculum. The results of the first phase are presented in the next section. The second phase called "Development of the Gamified GOAL platform," has as main steps the selection of a Learning Management System, its customization to the specific needs of the users, the integration of a gamification component and the creation of the MOOCs content. The results of this phase are presented in Sect. 4.

The third phase called "Pilot Evaluation and Results." In this phase, the evaluation goals, methodology, and instruments have been defined. In addition, the pilots have been conducted with the usage of GOAL platform and MOOCs to train athletes. The results of this phase are presented in Sect. 6, mainly focused on the impact assessment and retention rate of GOAL MOOCs.

3 Need Analysis and Curriculum Development

This section presents the current situation about the dual career in various European countries and as well as the athletes' needs and preferences.

3.1 Dual Career of Athletes in European Countries

As referred in the introductory section, there is a clear need for the development and support of the dual career of athletes. GOAL consortium has conducted a review of the current situation in various European countries (GOAL 2017). Important results of this survey are presented in this section. In UK, there are several dual career programs (and organizations, such as XPro and EAS Dual Career) to support athletes during their careers and transition. For example, Sport England (English Government) develops a Talented Athlete Scholarship Scheme (TASS) which aims to establish a wide web of educational possibilities to elite athletes. Some courses are proposed with athletes as target-group, particularly through the intervention of Professional Footballers Association, and Sector Skills Council 'Skills Active' (also English Government) provides an advanced apprenticeship in sporting excellence program in vocational education. It is important to refer that the UK has a significant and prestigious global position as a provider of e-learning courses (including in sports matters). In Greece, there is a comprehensive dual career policy, involving the Ministry of Sports, sports federations and universities, in order to support dual career of Greek athletes, but there is not an academic offer with athletes as target group and with special contents adequate to their particularities. In Portugal, there are three main organization who are developing dual career procedures and training: Portuguese Olympic Committee through the Olympic Athletes Commission, whom activity is related with the IOC Career Transition program, the Portuguese Government, whom have developed special legislation to support the dual career of athletes, and Portuguese Football Players' Union (SJPF) who offers several courses to its members. In Cyprus, there are, at the moment very limited activities and programs with the aim to raise awareness of the dual career of athletes and virtually no activities that aim to promote, support and facilitate the transition of athletes into the open market. In Poland, the market for dual careers is relatively small. But since 2014, successful athletes earn sports scholarships and so do the Olympians, for whom foundation OPUS Sport introduced a project giving an opportunity for active Olympians and Para-Olympians to acquire job experience through an internship in one company of their list of business that value athletes' personal character traits over their time availability. In Spain, the Spanish government and the Spanish Olympic Committee develop their own programs to support the dual career of athletes. Representative associations of athletes and football players also develop training and education facilities. There are many courses to support dual career of athletes, but most of them are not open to the public for free access. In Belgium, there is a strong task-force related with dual career. Vrije Universiteit in Brussels was a leader in GEES (Gold in Education and Elite Sport) Erasmus + project, where was developed the key competences for a successful dual career, and they are following promoting dual careers across Belgium sports agents, developing a Master program in Physical Education with a study path dedicated to Elite sports career. Beside Vrije Universiteit, there are special Government programs, like BLOSO in Flanders and "Project de vie des élites sportives" in Wallonia, which aim to organize the high-performance centres in the country and also to articulate high-level sports with education and employment and post-career transition.

In the European level, there are many initiatives and projects implemented in order to support of EU Guidelines on Dual Careers of Athletes (EU Guidelines on Dual Careers of Athletes 2013).

3.2 Athletes' Preferences

As it was presented by Stylianidis et al. (2018) a questionnaire (GOAL First Inventory) was delivered to more than a thousand athletes were given in order to measure their needs and see how familiar they are with distance learning and their experience in ICTs presents athletes' preferences for courses in a Dual Career MOOC. The indicative content of these courses is presented in Table 1.

After the needs analysis (presented in Table 2), the consortium decided that this platform will contain the following six courses of the curriculum organized in two cycles. The first cycle includes courses aiming to offer basic knowledge about entrepreneurship and personal skills development (decision-making skills, problem-solving skills, communication skills and teamworking skill. The courses of the second cycle are about sports management, sports marketing and coaching in sports.

4 Development of the Gamified GOAL Platform

The second step of GOAL project implementation was the development of the Gamified GOAL platform.

Firstly, a state-of-the-art about e-learning platforms have been conducted and the result was the selection of the most suitable platform that fits the project's needs.

In order to evaluate the existing e-learning platforms, an evaluation table was created, and importance points were assigned to features that are needed on the platform. Importance scale is 1 to 3, 1 slightly important, 2 important and 3 very important. If a platform qualifies for a feature it was assigned an X on the table. The values are summarized at the bottom of Table 3.

As, can be seen from the evaluation, the platforms that most suits the needs of the project is Moodle (https://moodle.org/).

Table 1 GOAL indicative list of courses

Course title	Short description
Personal Skills Development – Teamworking skills	Skills for working with others, namely: Accept constructive criticism, share information, Give
Personal Skills Development – Teamworking skills	Skills for working with others
Coaching in sports	Development at a basic level the principles and skills of coaching: skills for working with others, namely: Accept constructive criticism, share information
Personal Skills Development – Teamworking skills	Skills for working with others
Personal Skills Development – Decision-making skills	Abilities about knowing and practising good decision-making techniques
Sports Management	Integration of key concepts and theories in business administration and sports management, current trends and best practices
Personal Skills Development – Communication skills	Abilities to convey information to another effectively and efficiently
Personal Skills Development – Problem-solving skills	Abilities to accurately assess a situation and arrive at a positive solution
Sports Marketing	Marketing concepts and processes, and their relationship to the sports industry
Entrepreneurship:	Overview of entrepreneurship, including topics like identifying a winning business opportunity, gathering funding for and launching a business
Event Organization:	Planning, organizing, and managing event activities and the event environment
Sports writing & Broadcasting	Topics concerning reporting, interviewing and broadcasting skills
Personal Skills Development – Employability skills	Abilities that involve the development of a knowledge base, expertise level and mindset that is increasingly necessary
Career Orientation and Transition	Career management topics such as the changing employment reality, career stages, and career paths
Human Resources Management	Recruitment, selection, and maintenance of a qualified, motivated, and productive workforce
Personal Skills Development – Internet Technology Skills	Abilities to manage social networks, to use Internet services

As it was described before, GOAL team decided to use LMS Moodle and developed a MOOC platform using it. Moodle provides a wide range of plugins and solutions to enable gamification and create a friendlier and easily customizable, from the user perspective, environment. GOAL team used plugins such us “Level up” to create a gamified environment (Fig. 1).

After the needs collection and technological design, GOAL experts created the syllabus for each selected course and develop the appropriate learning material. This

Table 2 Athletes' preferences for courses in a Dual Career MOOC

Lessons	Count	%
Coaching in sports	532	10,56%
Personal Skills Development – Teamworking skills	449	8,91%
Personal Skills Development – Decision-making skills	441	8,75%
Sports Management	437	8,67%
Personal Skills Development – Communication skills	428	8,49%
Personal Skills Development – Problem-solving skills	381	7,56%
Sports Marketing	343	6,81%
Entrepreneurship	336	6,67%
Event Organization	336	6,67%
Sports Writing & Broadcasting	326	6,47%
Personal Skills Development – Employability skills	286	5,68%
Career Orientation and Transition	262	5,20%
Human Resources Management	245	4,86%
Internet Technology Skills	237	4,70%
Total	**5039**	**100%**

curriculum is provided in the form of MOOCs. The online lessons include serious games, reading material, online presentations and online tests all of them under a unified gamification framework. The evaluation of these MOOCs is presented in the next paragraph.

5 Evaluation Methodology

This section presents the evaluation goals, the instruments and participants. The pilots have taken place from September 2018 to December 2019.

5.1 Evaluation Goals

The main evaluation goals presented in the chapter are the following:

- G1: The impact of each GOAL MOOC to athletes' professional practice
- G2: The impact of the whole GOAL program of studies to athletes' professional practice
- G3: The athletes' level of knowledge in the disciplines supported by the MOOCs after the pilot period
- G4: MOOCs completion rate

Table 3 E-learning platforms state-of-the-art

Tools	Importance points (1–4)	E-Learning platforms						
		Moodle 3.3.1	Open e-class 3.5.6	Sakai 11	Atutor 2.2.2	Blackboard Learn 9.1	Dokeos CE	Open edx
Communication tools								
Discussion forums	2	X	X	X	X	X	X	X
Discussion Management	2	X	X	X	X	X	X	X
File sharing	2	X	X	X	X	X	X	X
Personal messaging	1	X	X	X	X	X	X	X
Collaboration tools								
Group work	3	X	X	X	X	X	X	X
Community Networking	3	X	X	X	X	X	X	X
System tools								
PHP/MySQL	3	X	X	–	X	X	X	X
Multilingual package	4	X	X	X	–	X	–	–
Developed plugins	4	X	–	–	–	–	–	–
Open source	4	X	X	X	X	–	X	X
Results								
		28	24	21	20	20	20	20

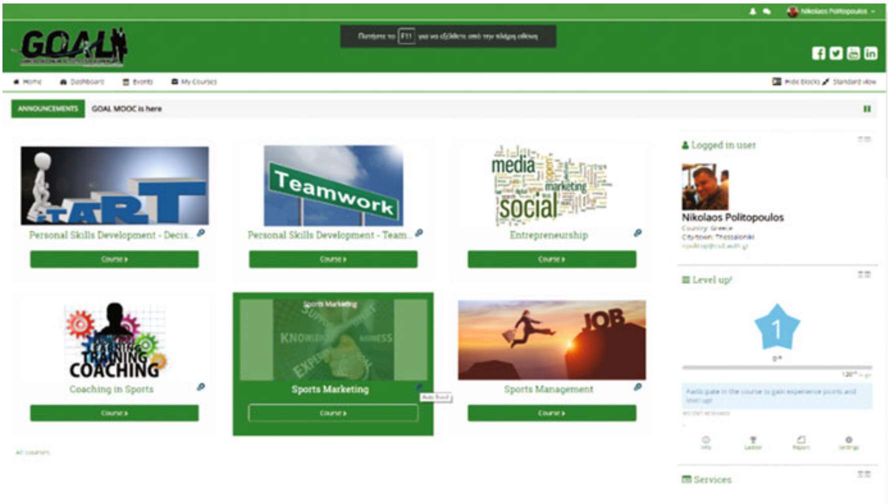

Fig. 1 GOAL MOOC prototype

5.2 Instruments

During the interaction of the user with platform relevant statistics of the performance of the users have been collected. Consolidation of the material as well as the new skills the athlete will acquire should be able to manifest in the progression of the athlete to a second career or the development of the existing second career. This can be accessed via a questionnaire that will be fulfilled by the users attending each of the GOAL's gamified learning courses.

The questionnaire can contain questions relevant to the impact of the course and the overall project to the existing dual career of the athletes or the help the course/project provided in the transition to the second career. Questions such as "Goal project provided me with skills that will help me transition in a new career after sports" can be scored on a 5-point Likert scale and can be analysed quantitatively. Example of the format of the questionnaire and the questions can be found in Table 4 below. This questionnaire was applied to every course and to the whole ecosystem of GOAL.

In order to measure the G3 (i.e. athletes' level of knowledge in the disciplines supported by the MOOCs after the pilot period), final quizzes, for every discipline, have been developed.

Concerning G4, the completion rate has been defined as the fraction of "Students registered to the MOOC" / "Students finished successfully the MOOC." The log files of the GOAL platform have been used in order to calculate this metric.

Table 4 Instrument to measure G1 and G2

	Strongly disagree	Disagree	Neither agree or disagree	Agree	Strongly agree
This course (name of the course) will change my professional practice	1	2	3	4	5
The degree of the change in my professional practice will be high due to this course (name of the course)	1	2	3	4	5
This course (name of the course) will improve my professional practice	1	2	3	4	5

5.3 Participants

At the end of the pilot training phase, 198 athletes had successfully completed one of the GOAL courses MOOC content. This means that they had answered, with a passing grade, all the topic quizzes, the final quizzes and completed the evaluation survey of course (Table 5).

6 Results

This section presented the results of the pilot's phase.

6.1 Impact of Each GOAL MOOC to Athletes' Professional Practice

This paragraph presents the "6.1. Impact of each GOAL MOOC to athletes' professional practice."

6.1.1 Personal Skill Development – Decision-Making and Problem

At the end of the pilot training phase, 36 athletes had successfully evaluated the "Personal Skill Development – Decision-Making and Problem-Solving Content." Most of them had experience in relevant courses. Thus, most of them believe that this course would have a great impact to their professional practice and would change and improve their professional career (Fig. 2).

Table 5 Athletes successfully completed GOAL (per course)

Courses	Athletes Enrolled Per Course	Athletes successfully completed course
Personal Skills Development – Decision-making skills	227	35
Personal Skills Development – Teamworking skills	141	33
Entrepreneurship	148	32
Coaching in Sports	164	37
Sports Marketing	113	30
Sports Management	131	31
Total	**924**	**198**

Fig. 2 Impact of the course to your professional practice (Personal Skill Development – Decision-Making and Problem)

Fig. 3 Impact of the course to your professional practice (Communication Skills and Teamworking Skills)

6.1.2 Communication Skills and Teamworking Skills

At the end of the pilot training phase, 36 athletes had successfully evaluated the Communication Skills and Teamworking Skills Content. Most of them had experience in relevant courses. Thus, most of them believe that this course would have a great impact to their professional practice and would change and improve their professional career (Fig. 3).

6.1.3 Entrepreneurship

At the end of the pilot training phase, 36 athletes had successfully evaluated the Entrepreneurship content. Most of them had experience in relevant courses. Thus, most of them believe that this course would have a great impact to their professional practice and would change and improve their professional career (Fig. 4).

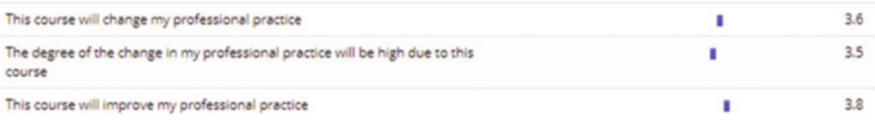

Fig. 4 Impact of the course to your professional practice (Entrepreneurship)

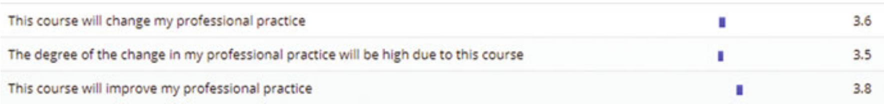

Fig. 5 Impact of the course to your professional practice (Coaching in Sports)

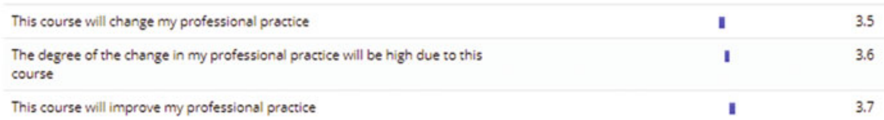

Fig. 6 Impact of the course to your professional practice (Sports Marketing)

6.1.4 Coaching in Sports

At the end of the pilot training phase, 38 athletes had successfully evaluated the Coaching in Sports Content. Most of them had experience in relevant courses. Thus, most of them believe that this course would have a great impact to their professional practice and would change and improve their professional career (Fig. 5).

6.1.5 Sport Marketing

At the end of the pilot training phase, 32 athletes had successfully evaluated the Sports Marketing content. Most of them had experience in relevant courses. Thus, most of them believe that this course would have a great impact to their professional practice and would change and improve their professional career (Fig. 6).

6.1.6 Sport Management

At the end of the pilot training phase, 32 athletes had successfully evaluated the Sport Management content. Most of them had experience in relevant courses. Thus, most of them believe that this course would have a great impact to their professional practice and would change and improve their professional career (Fig. 7).

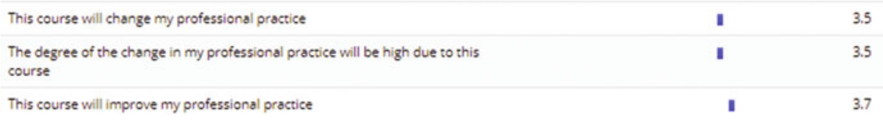

Fig. 7 Impact of the course to your professional practice (Sport Management)

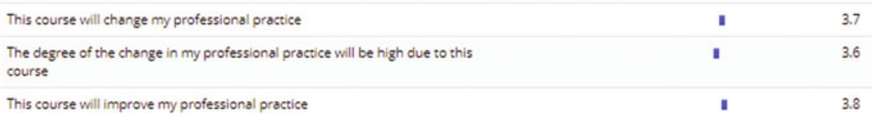

Fig. 8 Impact of the course to your professional practice (GOAL MOOC)

6.2 The Impact of the Whole GOAL Program of Studies to Athletes' Professional Practice

At the end of the pilot training phase, 21 athletes had successfully evaluated the GOAL MOOC Content (http://goal.csd.auth.gr/elearning/). The ecosystem includes the MOOC, the courses, the games and the services. Most of them had experience in relevant courses. Thus, most of them believe that this course would have a great impact to their professional practice and would change and improve their professional career (Fig. 8).

6.3 Athletes' Level of Knowledge in the Disciplines Supported by the MOOCs After the Pilot Period

The athletes' level of knowledge has been rated **very high** (between 9 and 10 out of 10 in the final quiz) in all courses except the sport management (where it was medium, with a score of about 4, 5 out of 10 in the final quiz). See Figs. 9, 10, 11, 12, 13, and 14.

6.4 MOOCs Completion Rate

Table 6 presents the completion rate (i.e. the fraction of "Students registered to the MOOC"/"Students finished successfully the MOOC").

The results are very promising because every GOAL MOOC presented **completion rate between 20% and 35% depending on the course**. It should be noted that the mean completion rate in all GOAL MOOCs is **26%**. This is a very promising impact of GOALMOOC model because as referred in the bibliography (a) the

Fig. 9 Mean scores in quizzes of all users (Personal Skill Development – Decision-Making and Problem-Solving)

average MOOC completion rate worldwide is less than 10%[1,2] (García-Peñalvo et al. 2018); and (b) among all MOOC participants worldwide, 3.13% completed their courses in 2017–18, down from about 4% the two previous years and nearly 6% in 2014–15.[3]

Other significant remarks are the following: (a) the course with the higher completion rate is "**Sports Marketing**"; (b) the country with the higher completion rate is **Cyprus** (about 43%); (c) the country with the most participants is **Greece** (about 301); (d) the course with the most enrolments is "**Personal Skills Development – Decision-Making Skills and Problem-Solving Skills**"; (e) the country with the

[1]MOOCs on the Move: How Coursera Is Disrupting the Traditional Classroom (text and video). Knowledge @ Wharton. University of Pennsylvania. 7 November 2012. Available at: https://knowledge.wharton.upenn.edu/article/moocs-on-the-move-how-coursera-is-disrupting-the-traditional-classroom/

[2]The MOOC pivot What happened to the disruptive transformation of education? http://www.umt.edu/provost/docs/MOOC-pivot.pdf

[3]https://www.insidehighered.com/digital-learning/article/2019/01/16/study-offers-data-show-moocs-didnt-achieve-their-goals

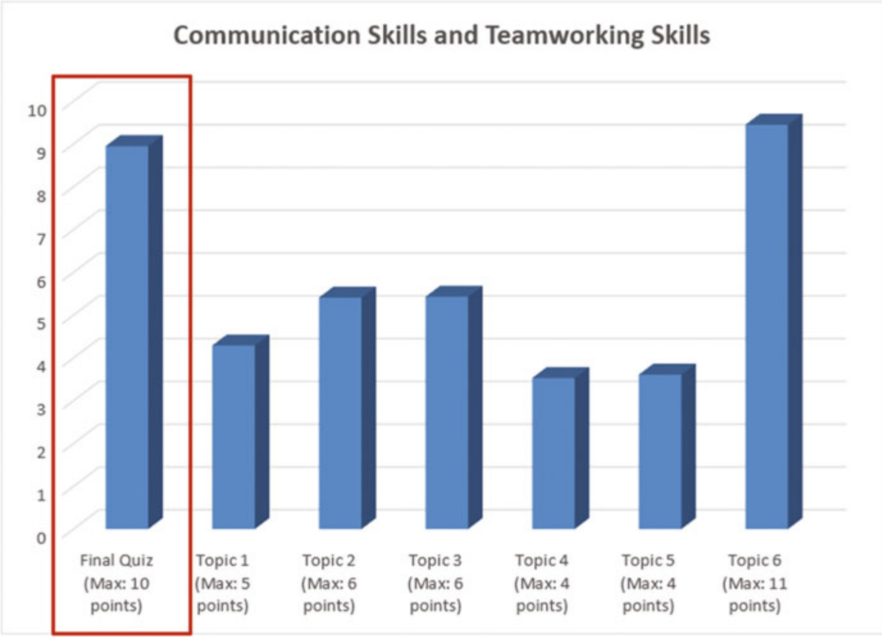

Fig. 10 Mean scores in quizzes of all users (Communication Skills and Teamworking Skills)

lower completion rate is **Portugal** (about 9%); (f) countries represented student-athletes (namely Greece, UK, Cyprus) presented higher completion rate (33%–34%) than the rest of the countries (9%–24%).

7 Discussion, Conclusion and Future Steps

As presented in the previous paragraphs, the results of the pilot study were very satisfying. More specifically, the impact is high (3.3–3.8 out of 5) of every GOAL online course and for the whole solution (3.8 out of 5) for the improvement of the professional practice of the athletes. Athletes' level of knowledge in the disciplines supported by the MOOCs is medium to very high in almost all courses. MOOCs completion rate per course is very high (between 20% and 35%), much higher than the worldwide average (~10%). MOOCs completion rate in total was also very high (26%). The adoption of e-learning model for training in Dual Career is very positive. About 69% to 100% of the students believe that the courses should be delivered via MOOC (18–40%) or mixed, meaning both online and onsite (51–78%). Users' opinion about the "Satisfaction" dimension was quite positive, since the mean value (M) is 4.17/5. Users' satisfaction of the Games was quite positive, for both serious games.

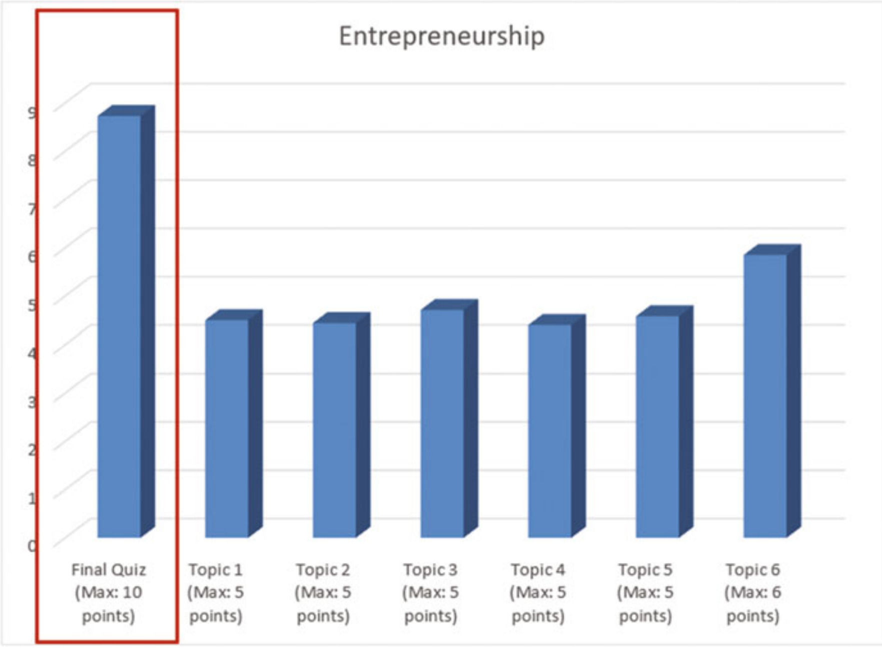

Fig. 11 Mean scores in quizzes of all users (Entrepreneurship)

The impact of the courses and the ecosystem were above expectations. Athletes believe that GOAL will change their future practice. They want to use the knowledge they acquired through their experience with GOAL and change their regular practices. They want to adapt to good practices they learned through the courses. In addition, the very high completion rate as well as the adoption of the whole GOAL solution are very encouraging results.

The GOAL consortium, after those promising results, decided to design a sustainability plan GOAL (2019) in order to allow athletes to visit the MOOC after the project's ending. There are three main steps towards a sustainable GOAL community. The first step is to offer the six GOAL MOOCs for free and charge the assessment module concerning the certification of attendance. The second step concerns the translation of the courses' content in the project languages, namely: French, Greek, Spanish, Portuguese and Polish and offer them for free with a payment of the assessment module concerning the certification of attendance. The third step is to create additional courses based on the athletes' needs. More specifically, Table 2 presents athletes' preferences for courses in a Dual Career MOOC. The first choices have already been implemented by GOAL project. The target of GOAL consortium is to implement the rest of the courses, namely Event Organization, Sports Writing and Broadcasting, Employability skills, Career Orientation and Transition, Human Resources Management, Internet Technology Skills.

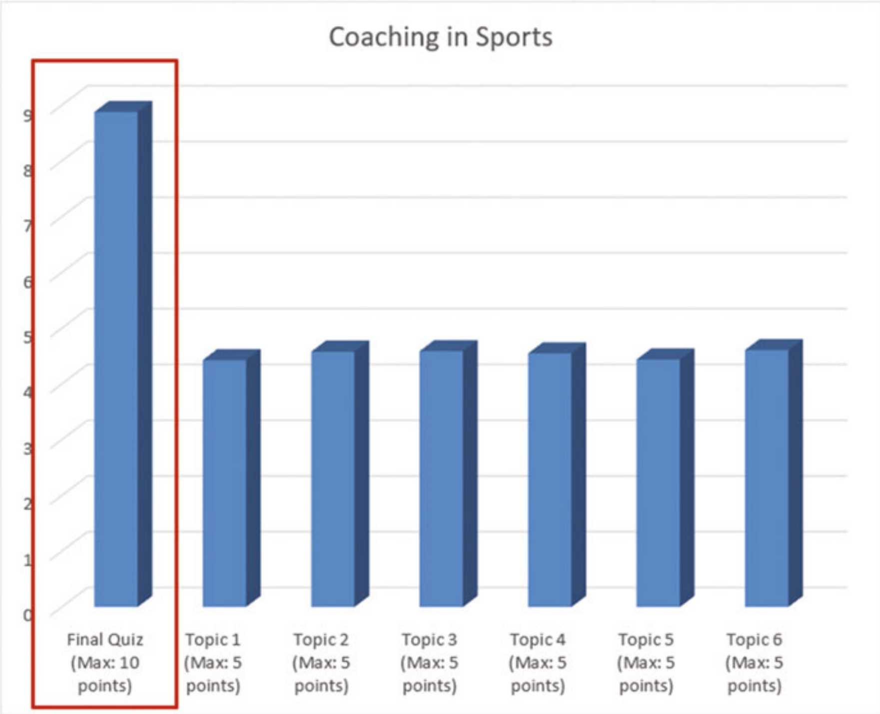

Fig. 12 Mean scores in quizzes of all users (Coaching in Sports)

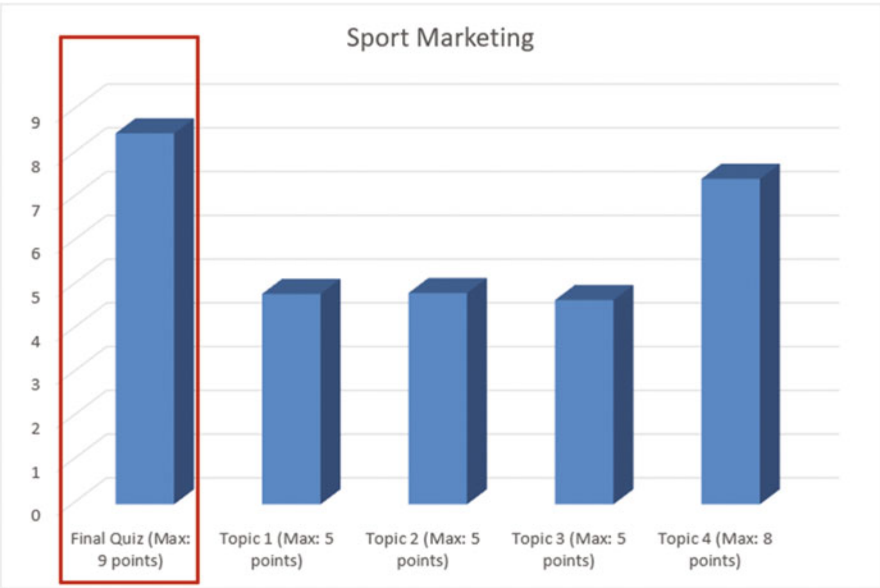

Fig. 13 Mean scores in quizzes of all users (Sports Marketing)

Fig. 14 Mean scores in quizzes of all users (Sports Management)

Table 6 Completion rate per course and per country

Countries/Courses	C1[a]	C2[b]	C3[c]	C4[d]	C5[e]	C6[f]	ALL
Greece	26%	28%	30%	40%	55%	46%	**35%**
UK	33%	25%	33%	33%	33%	50%	**33%**
Cyprus	25%	50%	50%	43%	60%	50%	**43%**
Poland	14%	33%	13%	20%	33%	20%	**20%**
Spain	17%	29%	32%	20%	29%	21%	**24%**
Portugal	11%	25%	10%	6%	9%	6%	**9%**
Other	8%	13%	13%	17%	17%	20%	**13%**
ALL Countries	**20%**	**28%**	**26%**	**24%**	**35%**	**27%**	**26%**

[a]Personal Skills Development – Decision-Making Skills and Problem-Solving Skills
[b]Personal Skills Development – Communication Skills and Teamworking Skills
[c]Entrepreneurship
[d]Coaching in Sports
[e]Sports Marketing
[f]Sports Management

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Human-Centered Design Principles for Actionable Learning Analytics

Yannis Dimitriadis, Roberto Martínez-Maldonado, and Korah Wiley

1 Introduction

The technology-enhanced learning (TEL) ecosystem is becoming increasingly complex, given the inclusion of new Information and Communication Technologies (ICTs). The COVID-19 global crisis has amplified this complexity, making it evident that ICTs will play a major role of the future of education at all levels. Indeed, all students will need at least some access to digital contents and tools from their homes and in the classroom. Thus, to address local and national restrictions and recommendations, hybrid learning spaces (Cohen et al., 2020) are and will be present due to the need for mixing teaching and learning modalities and spaces.

The affordances of ICTs are often powerful and presumably make teaching and learning more efficient and effective (Linn and Eylon, 2011), easing the life of the involved stakeholders. However, such complex TEL ecosystems will demand an extraordinary effort from the teachers as they will need to design appropriate learning scenarios, manage them under real-world conditions, and make decisions for the most effective pedagogical interventions. In other terms, teachers will face the challenge of carrying out the design and orchestration of the learning and teaching process in increasingly uncertain and complex TEL ecosystems (de Quincey et al., 2013; Goodyear, 2015).

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Learning analytics (LA) has emerged in the last decade as a powerful means to support teachers and other stakeholders (e.g., researchers, instructional designers, technology developers, administrators, and students) to navigate the complexities of teaching and learning in TEL ecosystems. The LA field deals with the measurement, collection, analysis and reporting of data about learners and their contexts, for purposes of understanding and optimizing learning and the environments in which it occurs (Siemens, 2012). More concretely, LA may provide support for the complete cycle of Teacher Inquiry into Student Learning (TISL) (McPherson et al., 2016) and evidence-based decision-making. In spite of all its advances and contributions, LA has not yet delivered on its promised potential, since the main LA proposals have not been able to provide sufficient actionable insights to the teachers (Sergis and Sampson, 2017) in their role of designers and orchestrators of complex TEL ecosystems (Gasevic et al., 2017).

Human-Centered Learning Analytics (HCLA) (Buckingham Shum et al., 2019), a significant trend observed in recent literature, claims that a human-centered perspective in LA might overcome several obstacles toward actionable tools and practices (i.e., LA solutions). For example, some HCLA guidelines suggest bringing teachers in the loop through intensive inter-stakeholder communication (Prestigiacomo et al., 2020); carefully exploiting the connection between learning design, monitoring, and learning analytics (Rodríguez-Triana et al., 2015; Maldonado-Mahauad et al., 2018); following a balanced design of artificial intelligence and human agents (Goodyear and Dimitriadis, 2013); or embedding learning theory through the teachers' technological pedagogical content knowledge (TPACK) (Wiley et al., 2020).

In this chapter, we investigate the role of LA solutions in supporting an evidence-based approach to teaching and the importance of inter-stakeholder collaboration for making design decisions in such complex TEL environments. Focusing on teachers as key LA stakeholders, designers, and orchestrators, we study how LA can be designed to position teachers as designers of effective pedagogical interventions and orchestration actions. To address this overall goal, we adopt a human-centered design (HCD) perspective of LA, taking advantage of existing knowledge in the design and human-computer interaction (HCI) communities while considering the specific characteristics of learning and teaching. With this perspective, we offer and illustrate HCD principles to guide the process of designing and orchestrating actionable LA solutions.

The rest of this chapter is structured as follows: Sect. 2 provides an extensive description of the most relevant concepts and research lines regarding learning design, orchestration, learning analytics, and HCD for LA. Our principles for the HCD process are described in Sect. 3. Section 4 describes two illustrating examples of how the HCD principles can be implemented. Finally, Sect. 5 discusses open issues, draws the main conclusions, and points at future research and development directions.

2 Background

2.1 Current Approaches for Designing for Learning, Analytics, and Orchestration

Teachers (supported by other stakeholders such as researchers, system developers, and instructional designers) need to design and orchestrate the increasingly complex TEL environments. As Goodyear (2015) suggest, one can design for the social architecture (the groupings of students that are most appropriate), the tasks to be performed (not the activities that depend on the learners' actions and decisions), and the physical and digital environment (the tools that will be employed, the artifacts that will be created and evolved throughout the activities, and the resources that are available). The design outcomes should be effective and efficient processes for making configurations, monitoring learner performance and engagement, executing orchestration actions, and making and implementing decisions for redesign and interventions.

On the other hand, a decade of research in LA has produced significant outcomes, especially in mining patterns of student behavior based on trace data (Luckin et al., 2010), deriving predictive models regarding performance and dropout (Ranjeeth et al., 2020), and providing dashboards to make sense of the behavioral data (Kali et al., 2015). However, most research and development efforts have been centered on exploiting powerful data by applying well-known artificial intelligence (AI) and data science (DS) methods to new datasets of clickstreams, mainly serving administrators and researchers. More impact is being sought to enable the main stakeholders, i.e., students and teachers, to take advantage of actionable insights provided by meaningful indicators and LA tools in authentic contexts (Hunziker et al., 2011). Thus, there is an urgent need to study how LA solutions can be designed for effectively supporting pedagogical interventions and orchestration actions.

Yet, a critical question arises: Should the technology (e.g., AI) substitute teachers or mediate orchestration through tools that balance the orchestration load (Sharples, 2013)? For example, some tools may hold substantial agency by automatically intervening and regulating the learning activity, like it occurs with intelligent tutoring systems (ITS). By contrast, LA tools may mirror rather than directly orchestrate what occurs in the TEL ecosystem. Such tools can recommend orchestration and redesign actions or help teachers to monitor the learning activity and make informed decisions (Soller et al., 2005). However, finding the right balance between humans and digital tools with respect to the orchestration load and agency can be challenging (Goodyear and Dimitriadis, 2013). Eventually teacher augmentation might be pursued to bring such balance (An et al., (2020)), since scholar design knowledge can be embedded in tools and can complement both the tacit and explicit design knowledge of teachers, typically expressed through teachers' TPACK (i.e., their joint knowledge on content, pedagogy, and technology) (Knight et al., 2020). Therefore, how can the different stakeholders form part of a design team, in which the different types of expertise can be fully considered? We argue that teachers (and learners) can serve as designers (Jørnø and Gynther, 2015; Gasevic et al., 2019) and, as such, they should participate in not only the design and orchestration of the teaching and learning processes but also the associated support tools.

In recent literature, several design principles and approaches toward effective LA practices and tools have been proposed. These principles and approaches consider the role of the involved stakeholders and take advantage of the relation between learning design, learning analytics, and learning environment. For example, Beer et al. (2019) suggested that educational theory and the characteristics of the learning task should provide guidance for design aspects in learning analytics including data selection, data analysis, and implementation. Wise and Vytasek (2017) proposed three design principles within their Learning Analytics Implementation Design (LAID) framework on how LA solutions might be designed and implemented in practice. The LAID principles are based on an assertion that LA and learning design are intimately intertwined (Rodríguez-Triana et al., 2015; Maldonado-Mahauad et al., 2018). On the one hand, LA may provide evidence that informs about the effectiveness of learning design and supports the Teacher Inquiry into Student Learning process, i.e., provide them actionable insights on how to orchestrate and redesign. On the other hand, learning design can frame what are the analytics to be generated, guide the way analytics may be meaningfully interpreted, and eventually inform and recommend teachers and students to take decisions.

Accordingly, Wise and Vytasek (2017) suggest coordinating (conceptually and logistically) the LA solution with respect to the overall learning design so that appropriate data and indicators are selected for generating analytics that can be understood by teachers. They also suggest, albeit with caution, comparing learner metrics against an absolute value set by the learning objectives or a relative tendency across courses or across different activities of the same learner. Furthermore, they suggest customizing the LA system to the needs and profiles of its users, through either an adaptive LA system (where AI agency becomes predominant) or a solution that can be configured based on the preferences of the users (where the engagement of the teacher/student is crucial in all phases of the design, development, and enactment phases).

As mentioned above, dominant LA solutions have been mostly built using knowledge from Data Science. Considering limitations of those LA solutions, Gašević et al. (2015) proposed a consolidated model in which learning analytics lies at the intersection of learning *theory*, *design*, and *data science*. These authors particularly emphasize the critical role of educational theories for designing actionable LA solutions that can be relevant to the learning task at hand and meaningful to teachers and students. In the same vein, Reimann (2016) suggests, more is needed than just data to discover meaningful relations and Echeverria et al. (2018) suggest, in the title of their paper, "Let's not forget: Learning analytics are about learning." On the other hand, design has not been as deeply explored as data science and theory, and the amalgamation of the three is far from being mature. But learning theory, design principles for the LA solution, or data science methods may not be sufficient if we do not define principles that govern the process for designing LA solutions that can be orchestrated and adopted in practice.

Addressing this, Prestigiacomo et al. (2020) argued for the need for a strong inter-stakeholder communication and provided instruments for expressing needs and knowledge. Their analysis of the obstacles of LA adoption from the orchestration lens led to the recommendation of using the OrLA (Orchestrating Learning Analytics) framework to guide the LA design process. Thus, effective orchestration support, including LA solutions, should enable teachers to design and configure the learning environment, monitor the learning activities, and become aware of what is going on. This suggests the need for participatory and co-design methods that could be used to imbue LA solutions with the needs and preferences of the stakeholders while taking into account all practical classroom constraints as well as the theories regarding learning and teaching.

2.2 Human-Centered Design for Learning Analytics

The term Human-Centered Learning Analytics (HCLA) has recently emerged in the LA community of research to refer to the adoption and adaptation of design practices, well-known in HCI, with the purpose of engaging educational stakeholders, such as teachers, students, and educational decision-makers, in the design process of data-intensive educational innovations (Buckingham Shum et al., 2019). The main paradigm shift proposed by design communities, such as participatory design (Schuler and Namioka, 1993) and co-design (Bannon and Ehn, 2012), is to move from *designing for users* to *designing with people* as equal partners in the design process (Sanders and Stappers, 2008). The aim is to make the most of the creativity of designers and people not formally trained in design, but that can have other relevant types of expertise, by letting them work together across the whole span of the design process.

Therefore, HCD approaches are relevant for creating LA interfaces aimed at effectively supporting teachers and students in making decisions in terms they can make sense of and use. However, work in this area is embryonic in LA, with a growing number of pioneering researchers advocating for rapid cycles of prototyping with teachers (e.g., Mangaroska and Giannakos, 2018) and conducting interviews with students to generate a deeper understanding of their perspectives on data analytics (e.g., Mavrikis et al., 2019). Goodyear and Dimitriadis (2013) were among the first researchers in adapting various generative (or ideation) tools and co-design techniques to identify teachers' data needs and design prototypes of awareness and orchestration tools to be used with ITSs in the classroom.

Teachers have been the most commonly involved group of stakeholders in LA co-design studies thus far (Buckingham Shum et al., 2019). For example, Ahn et al. (2019) established partnerships with teachers to design an LA dashboard that meets the local needs of a particular educational context. Similarly, Dillenbourg et al. (2019) discussed how participatory semi-structured interviews can be organized to engage teachers in long-term LA projects. Martinez-Maldonado et al. (2019) organized participatory workshops with teachers as an entry level for them to learn to use authoring tools in the context of an ITS that provides automated feedback. Wise and Jung (2019) combined LA interface walkthroughs and transcript analysis to generate understanding of how teachers can effectively make sense of student data and, thus, designed a teacher dashboard accordingly. They proposed a process model of how instructors may use LA, in which they connect sense-making with pedagogical response, iteratively and bidirectionally, going from questions of interest to reading data and explaining patterns, taking action, waiting and seeing, or even reflecting on their pedagogy, before checking the impact of their actions. Similarly, Mor et al. (2015) proposed a method to run participatory workshops in order to elicit data needs from pre-service school teachers to understand what kinds of analytics can effectively support their evidence-based teaching practices.

Some examples of LA design projects that engage various stakeholders besides teachers have also started to emerge. For example, Prieto et al. (2019) developed a tool to facilitate design conversations between teachers and students, using a learner journey technique, to jointly identify the form and opportunities for providing automated feedback to students in the context of nursing education. The same authors developed a deck of design cards to facilitate co-design sessions by scaffolding the conversations and addressing potential power inequalities by ensuring all stakeholders have a voice in the design decisions (Alvarez et al., (2020)). This approach is similar to that of Vezzoli et al. (2020) who proposed using inspiration cards to engage teachers in early stages of the design process of an LA system. HCLA conceptual and empirical work particularly aimed at giving students an active voice in the LA design process are also starting to emerge (Prieto-Alvarez et al., 2018; Prieto et al., 2019).

In summary, these studies demonstrate the growing interest in bringing HCD approaches in LA. However, most of these papers have reported local projects and particular solutions that can certainly inspire other researchers to organize co-design sessions in their institutions.

The next two sections of this chapter conceptualize the process of designing and orchestrating actionable, human-centered LA solutions, through the proposal and discussion of principles, and their illustration using case studies in authentic contexts.

3 Principles for the Process of Human-Centered Design

After providing a brief view of what have been the main trends of LA research and based on the aforementioned literature survey and authors' first-hand experience in co-designing LA innovations with teachers and other stakeholders (to be presented below), we can conceptually distil three basic HCD principles to govern the process of designing actionable LA solutions:

1. Agentic positioning of teachers and other stakeholders
2. Integration of the learning design cycle and the LA design process

3. Reliance on educational theories to guide the LA solution design and implementation.

The three principles reflect a human-centered perspective, since learning design and orchestration are typically carried out by teachers and instructional designers and educational theories are produced by researchers.

3.1 HCD Process Principle #1: Agentic Positioning of Stakeholders

The primary objective for the agentic positioning of relevant stakeholders during the design process is to facilitate the exchange of expertise and the development of a mutual understanding of each stakeholder's priorities, values, and constraints. In other words, the voices and expertise of all relevant stakeholders should be considered and leveraged, respectively, in the LA design process. However, a major challenge in meeting this objective is facilitating this communication. In some cases, this challenge can be managed by careful planning to permit meetings in which all stakeholders can engage synchronously in time and/or space. In other cases, stakeholder meetings can occur asynchronously through communication media, whether digital or analog. The stakeholder forms described by Prestigiacomo et al. (2020) can support such inter-stakeholder communication, as they guide both the content of information exchange and the sequence of stakeholders' responses. The work on human-centered design presented in Sect. 2.2 supports this principle, together with the literature review that motivates the OrLA framework (Prestigiacomo et al., 2020).

3.2 HCD Process Principle #2: Integration of the Learning Design Cycle and LA Design

Asensio-Pérez et al. (2017) describe the learning design cycle as a three-phase process consisting in rounds of creation, orchestration, and assessment (Fig. 1). The cycle begins with the creation of specific tasks, intended social structures, artifacts, and resources to facilitate the desired learning process. During the orchestration phase, the learners' engagement with these elements is monitored, regulated, and scaffolded with the goal of supporting the desired learning. Learners' artifacts are then assessed to determine how the learning design can be redesigned or reinstituted to achieve the desired learning.

Integrating the process of LA development with the learning design cycle can enable LA solutions to effectively support Teacher Inquiry into Student Learning and evidence-based decision-making. To illustrate, after creating the learning design, specific elements of the design are identified as targets for the LA tool

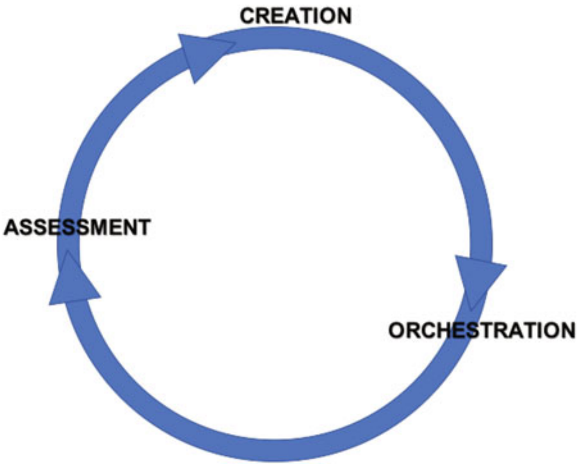


Fig. 1 The three phases of the learning design cycle: creation, orchestration, and assessment

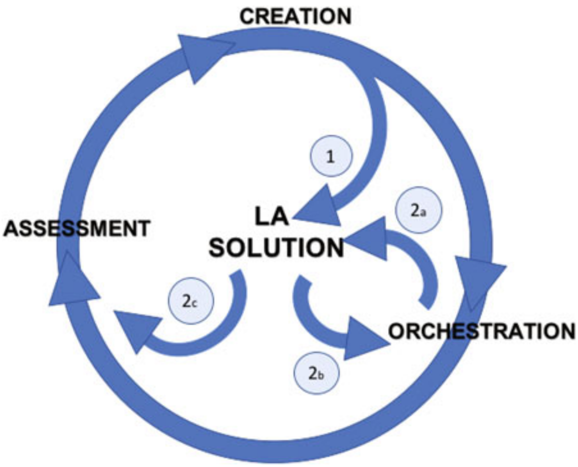


Fig. 2 The integration of LA development into the learning design cycle. (1) LA design, learning design elements selected as targets for LA solution, (2) LA implementation: (**a**) data from LA targets is analyzed by the LA tool, and the resulting LA informs, (**b**) orchestration, (**c**) and assessment

(Fig. 2, 1). During the orchestration phase, the LA tool is implemented. The selected targets feed data into the LA tool (Fig. 2, 2a), and the subsequent analysis by the LA tool supports the understanding of the learning taking place and informs the pedagogical interventions and orchestration actions needed to optimize that learning process (Fig. 2, 2b). The output from the LA tool can also support the assessment phase of the learning design cycle, by providing insight into the effectiveness of the targeted elements in facilitating the desired learning outcomes (Fig. 2, 2c). This principle was inspired by the related work described in Sect. 2.1 and especially by Rodríguez-Triana et al. (2015), Maldonado-Mahauad et al. (2018) and Wise and Vytasek (2017).

Achieving the alignment of these two processes can be complicated by the fact that typically no single stakeholder is responsible for all aspects. For example, a system developer may design an LA solution for a learning design that a researcher or instructional designer creates and a teacher orchestrates. However, the challenges associated with aligning the two processes can be mitigated by implementing HCD process principle #1, namely, increase the likelihood that the voices from all relevant stakeholders be considered in the LA design process, regardless of the configuration of stakeholder responsibilities.

3.3 HCD Process Principle #3: Educational Theory Guidance

For this principle, we assume that the learning design has been developed in accordance with an educational theory (i.e., a theory of learning or research-based professional standards). As such, the educational theory that guides LA design and implementation should be the same as that used for the learning design. During the LA design process, educational theory informs the selection of data and extracting metrics that can be associated with higher-order meaningful constructs relevant to the learning design at hand. Moreover, educational theory can inform how to use the LA to generate actionable insights and inform orchestration actions and help to identify the goal toward which learning and its environment are optimized (i.e., learning design redesigns). A potential challenge in meeting principle #3, particularly when viewed in light of principle #2, is when the learning design is created by stakeholders without intimate knowledge of educational theories. In such case, a knowledgeable stakeholder can retroactively apply an educational theory to the learning design to inform LA data selection and analysis. However, LA targets that do not align with the theory may need to be excluded from the candidate pool to realize the benefit of this principle. The work by Gašević et al. (2015) and Reimann (2016), presented in Sect. 2.1, has mainly motivated the proposal of this principle.

In the next section, we describe two studies that illustrate how to implement these HCD process principles during LA design.

4 Illustrative Studies

4.1 Study 1: A Performance Analysis Tool for an Online Middle School Science Unit

This study illustrates how the three HCD process principles for designing effective LA solutions can be implemented when a learning design is created by multiple stakeholders. Specifically, it is a design-based research (DBR) study, consisting of a 2-year partnership involving three researchers, three system developers, and five middle school science teachers. The study goal was to develop an activity-centered LA solution (Klerkx et al., 2017) for a Web-based Inquiry Science Environment (WISE) unit on global climate change. Given its call for a design process that is participatory and theory-grounded (Sandoval and Bell, 2004), DBR functioned as a scaffold for implementing HCD principles #1 and #3. To further implement principle #1, the study methods included inter-stakeholder dialogues (Prestigiacomo et al., 2020) for which the researchers served as liaisons between stakeholder groups. While the unit activities were created by the researchers, teachers designed and interleaved their own offline activities to complete the science instruction for their students. Thus, the complete learning design, the WISE unit plus the teacher-provided offline instruction, was co-designed. Therefore, inter-stakeholder dialogue (Prestigiacomo et al., 2020) was essential for developing an LA solution that incorporated the design knowledge of each stakeholder. These in-person, inter-stakeholder discussions were guided by the three LAID principles (i.e., coordination, comparison, and customization; Wise and Vytasek, 2017), which helped stakeholders attend to issues relevant for designing an LA solution that could be effectively implemented in classrooms.

The researcher-teacher meetings focused on issues related to all three LAID principles, such as presenting and explaining the unit's learning design and underlying theory of learning, understanding teachers' goals and priorities for assessing and supporting student learning, and discussing the impact and influence of the LA solution on teaching and learning. From these meetings, the stakeholders decided that the LA tool would provide teachers with data related to seven multiple-choice items that engaged students in distinguishing their ideas about how the sun warms the earth (Fig. 3). More specifically, the LA tool would provide teachers with aggregated and individualized data on students' answer patterns for the seven multiple-choice items. These unit items were chosen because they both aligned with the focus of teachers' offline activities and functioned as measures for the higher-order construct targeted by the learning design, namely, distinguishing ideas.

The unit's learning design was designed in accordance with the Knowledge Integration (KI) pedagogical framework (Koehler et al., 2013), which operationalizes the constructivism theory of learning. This theory holds that learners construct new knowledge by building on their prior ideas. In a KI-based learning design, student's topic-related ideas are first elicited, after which students are provided with opportunities to discover new ideas, make distinctions among the ideas, and finally make relevant connection between ideas. Prior research identified the distinguishing ideas step as particularly challenging for students to engage in Vitale et al. (2016) and for teachers to support (Wiley et al., 2019).

Integrating the first cycle of LA design with the unit's learning design cycle allowed the LA tool to serve as an evaluative tool for how well the unit's learning design was supporting the desired learning (ref. Fig. 2, 2a-c), which for this study was integrated knowledge of concepts related to global climate change. The LA revealed that students who did not correctly answer the multiple-choice items also did not heed the feedback to review the related simulation where they could discover the relevant ideas. This information provided the researchers with the insight needed to restructure the unit. They did so by placing the assessment items, which supported students in distinguishing ideas, on the same page as the related simulations, which facilitated the discovery of new ideas.

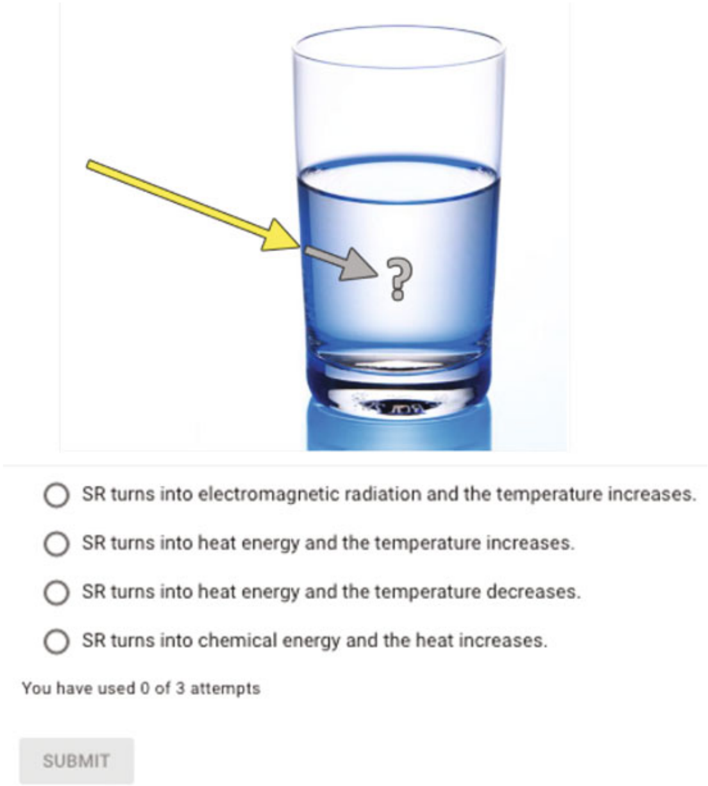
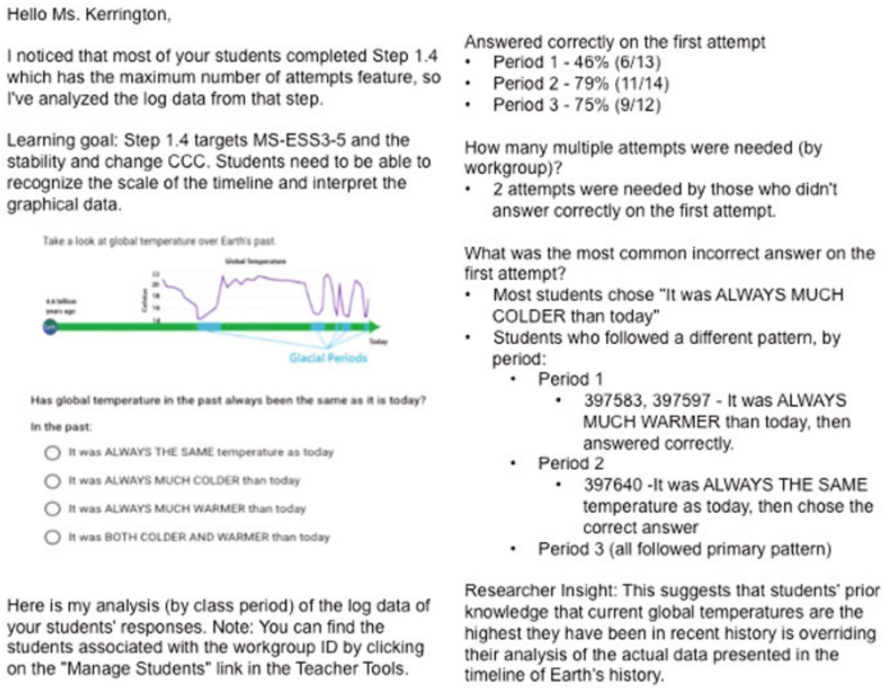


Fig. 3 Example of a multiple-choice item from the WISE Global Climate Change unit that was selected as a target for the LA tool. Note: *SR* solar radiation

The second cycle of LA development was integrated into the learning design cycle for the offline teacher-created activities. During this cycle the "reseacher-system developer" meetings functioned prominently. These meetings focused on issues related to the coordination and customization principles, such as the researchers understanding the WISE system capabilities, the system developers understanding the objectives and priorities of the researchers and teachers, and workflow management for developing the LA artifact. From these meetings, the stakeholders decided to create an LA report as the artifact. Teachers received an LA report for each assessment item after completion by a majority of students (Fig. 4). Drawing on the principles for data storytelling (Echeverria et al., 2019), the analytics in the report were contextualized by presenting them directly beneath the question prompt, learning objective, and aligned science standard. This contextualization was designed to orient and remind teachers of the unit's researcher-created learning design. Additionally, the LA report included a researcher-created hypothesis, called Researcher Insight, to explain the students' performance and to identify their potential learning needs. In this cycle of the DBR process, the Researcher Insight



Hello Ms. Kerrington,

I noticed that most of your students completed Step 1.4 which has the maximum number of attempts feature, so I've analyzed the log data from that step.

Learning goal: Step 1.4 targets MS-ESS3-5 and the stability and change CCC. Students need to be able to recognize the scale of the timeline and interpret the graphical data.

Take a look at global temperature over Earth's past

Glacial Periods

Has global temperature in the past always been the same as it is today?

In the past:

- It was ALWAYS THE SAME temperature as today
- It was ALWAYS MUCH COLDER than today
- It was ALWAYS MUCH WARMER than today
- It was BOTH COLDER AND WARMER than today

Here is my analysis (by class period) of the log data of your students' responses. Note: You can find the students associated with the workgroup ID by clicking on the "Manage Students" link in the Teacher Tools.

Answered correctly on the first attempt

- Period 1 - 46% (6/13)
- Period 2 - 79% (11/14)
- Period 3 - 75% (9/12)

How many multiple attempts were needed (by workgroup)?

- 2 attempts were needed by those who didn't answer correctly on the first attempt.

What was the most common incorrect answer on the first attempt?

- Most students chose "It was ALWAYS MUCH COLDER than today"
- Students who followed a different pattern, by period:
  - Period 1
    - 397583, 397597 - It was ALWAYS MUCH WARMER than today, then answered correctly.
  - Period 2
    - 397640 -It was ALWAYS THE SAME temperature as today, then chose the correct answer
  - Period 3 (all followed primary pattern)

Researcher Insight: This suggests that students' prior knowledge that current global temperatures are the highest they have been in recent history is overriding their analysis of the actual data presented in the timeline of Earth's history.

Fig. 4 This is a reconstruction of the emailed LA report that was sent to teachers after at least 50% of students completed the associated multiple-choice item

was generated manually by the researcher based on the analysis of student work and unit navigation patterns using clickstream data. In the following cycle, data was fed automatically from the analysis module to the LA dashboard.

Since the LA solution aligned with the learning design knowledge of both researchers and teachers (i.e., aligned to unit items that measured constructs targeted by both researcher- and teacher-created learning activities), it was able to support teachers in designing and redesigning their orchestration actions and pedagogical interventions. For example, in one researcher-teacher meeting, a teacher described his LA-supported actions as follows:

> I review the most common incorrect answer and have table talks and then classroom discussions about why students might have that as a misconception, why it's a misconception, and why the correct answer is correct. For a couple of the questions, I have supplemented the classroom discussions with various simulations and videos to try and change the students' understanding of the misconception. (Wiley et al., 2019, p.576)

Informed by the analysis presented in an LA report, another teacher decided to redesign his classroom instruction to implement more pre-activities that help students understand their background knowledge. This redesign highlights how the LA solution captured the researcher and teachers design knowledge, as this teacher's redesign aligned with the theory used to design the unit, namely, eliciting students' prior ideas to make them available for further knowledge development.

The actions that teachers took in response to the LA solution, while consistent in many ways with the design knowledge of the researchers, also reflected their individual TPACK. The freedom that teachers had to reconfigure the learning environment and scaffold students in accordance with their TPACK without conflicting with the design knowledge of the researchers and system developers illustrates the value of the three HCD principles shown in Sect. 3: agentic positioning of key stakeholders, integration of the learning design cycle and LA development, and guidance by a theory of learning.

4.2 Study 2: A Multimodal Reflection Tool for Healthcare Simulation

This study illustrates how meeting the three HCD principles for creating effective LA solutions occurred in close partnership with relevant stakeholders with the purpose of creating an LA tool that explicitly reflected the learning intentions of the educator. This involved a long-standing 4-year partnership with two healthcare researchers, six LA researchers, two teaching support staff members, three nursing lecturers, and various nursing undergraduate students representing diverse and intense stakeholder involvement. The goal of the study was to develop a reflection tool to be used to support team debriefing in nursing simulation (Martinez-Maldonado et al., 2015). These simulations involve face-to-face classes of 25–30 students led by one educator. The classrooms are simulated hospital wardrooms with high-fidelity patient manikins located on 5–6 beds. The educator commonly starts the class with some explanations, followed by students breaking into smaller teams. After the teams complete their simulations, the educator leads a class debrief. In this context, educators often create their learning designs based on clinical theory and national healthcare guidelines for the purpose of accreditation and for students to develop the graduate attributes they need to become registered nurses. We focus on one of such designs in which students are required to provide basic life support (BLS) to a simulated patient after he lost consciousness.

An initial set of co-design sessions involved inter-stakeholder communication using OrLA forms (Prestigiacomo et al., 2020) asynchronously for the healthcare researchers, LA researchers, teachers, and system developers to identify data and orchestration needs and how these data could be feasibly captured. The stakeholders identified multimodal sources of evidence educators could use to provide feedback to students. As a result, the learning space was instrumented using a combination of sensors and an annotation console that could be orchestrated by the teaching support staff members or the LA researchers. Additional co-design sessions were organized with educators and students to identify particular characteristics of the LA tool including graphical interface and interaction design requirements and the medium

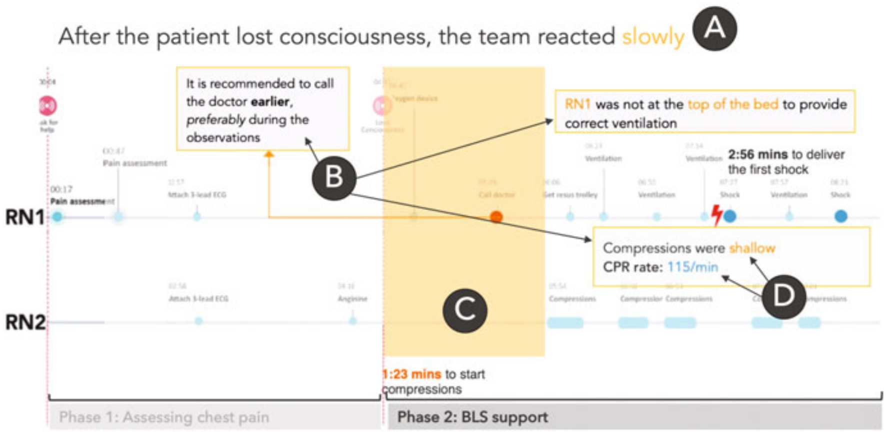


Fig. 5 Team timeline highlighting errors observed during phase 2 of the simulation (BLS support) for one team of nursing students. Errors are highlighted using visual elements such as (**a**) a prescriptive title, (**b**) text annotations, (**c**) shaded areas, and (**d**) color encoding (orange and blue for errors and correct actions, respectively)

to be used. Techniques such as focus groups, learner journey-mapping, and rapid prototyping were used in facilitated sessions (Prieto et al., 2019). A visualization was created to provide feedback on students' performance by highlighting errors (e.g., critical actions missing or performed in the wrong order) and delays using logged actions and positioning traces of each nurse (Fig. 5).

A mapping was performed from low-level data to clinical constructs that educators and students could understand. For example, the higher-order construct targeted in the exemplar simulation corresponds to the effective performance of BLS. According to clinical literature (Holstein et al., 2019) and national guidelines (ANZCOR, 2016), four subconstructs were selected by the educator to assess students' performance, such as opening patient's airway, and partly modeled based on the positioning data and logged actions.

The educators' learning design served to configure the LA tool for the interface to be aligned with these four subconstructs as learning goals. A data storytelling approach (Echeverria et al., 2019) was followed for making the learning goals explicit in the LA interface. Each learning goal is assessed against learners' data (using rule-based algorithms) to automatically generate visual and textual elements to enable educators and students to understand whether the learning goal was accomplished and receive feedback on areas of improvement. For example, Fig. 5 presents one of such data stories for a team of two nurses who performed chest compressions (subconstruct 3) slowly and shallowly (Dollinger et al., 2019). The visualization is enhanced with text explaining to students the errors they made.

In this illustrative study, the voices of various relevant stakeholders were considered, first, to understand the data and orchestration needs of teachers and how the hybrid learning space could be instrumented with sensing technology with integrity and considering practical aspects that may affect orchestration (HCD principle #1). Teachers, students, and healthcare researchers were further involved in the design process of the tool and the strategies to embed the tool into the current teaching and learning practice. The alignment between the LA solution and the learning design was made explicit in the LA tool itself, based on the data storytelling paradigm, in which each learning goal established by the teacher is co-configured in the learning design phase for the tool to provide feedback via a combination of text and visual enhancements: data stories pre-configured by the teacher (HCD principle #2). Although in the study this preconfiguration was performed by the LA researchers, based on the outputs from the co-design sessions with teachers, this configuration can eventually be automated or be part of the responsibilities of a stakeholder in charge of the learning design. Finally, this case also shows how theory can guide the design and implementation of the LA solution (HCD principle #3). Although the theory the teacher explicitly considered in this example comes from clinical literature instead of educational literature, similar simulation-based pedagogical approaches are used in other educational areas and levels, beyond the healthcare sector.

5 Discussion and Conclusions

Learning analytics solutions may contribute to more effective and efficient design for learning and orchestration, allowing for informed decision-making, pedagogical interventions, and orchestration actions. However, learning analytics has not delivered yet up to its potential through the provision of actionable insights to the main stakeholders, i.e., teachers and students. A human-centered design approach for learning analytics has emerged in recent years, although it is still a toddler, aiming to bring together all relevant stakeholders through participatory design, co-design, design-based research, and research-practice partnerships. In this chapter we focused on the role of teachers as designers and their connection with researchers, system developers, and other stakeholders in the process of designing and implementing learning analytics solutions, i.e., tools and practices. We called for strong inter-stakeholder communication, and we proposed three human-centered design principles for learning analytics, which were illustrated through two case studies in authentic contexts. In both studies, teachers became active agents in the design process of the LA solution (HCD principle #1). The studies demonstrated how the voices from multiple stakeholders are needed not only to consider teaching and learning aspects but also to connect these with technical and practical requirements that can impose limitations on what can be achieved with the resources available. The studies proposed two different ways to integrate the learning design cycle and the LA design process (HCD principle #2), by enabling teachers to assess their learning design based on the analytics (study 1) or by imbuing the analytics with the pedagogical intentions stated in the teacher's learning design (study 2). Finally, we also illustrated the power of educational theory for designing meaningful LA solutions (HCD principle #3). Study 1 demonstrated how a well-known theory of learning drove critical design aspects of the LA solution through the Knowledge Integration (KI) pedagogical framework. By contrast, study 2 illustrated a more specific instance in which clinical theory was embedded into a simulation-based learning pedagogical approach to drive both the learning design and the design of the LA interface. In sum, the proposed principles ask for stronger involvement and agency of the teachers, so that all voices of involved stakeholders can be considered, integration of the learning design cycle and the LA design process, and reliance on educational theories to guide the LA solution design and implementation. This way, targets can be defined based on the learning design and pedagogically sound theories, reflecting both scholar and practitioner design knowledge, so that meaningful analytics can be determined and appropriate support for interventions, orchestration, and redesign can be provided.

However, it is still necessary for the research community to move forward and address multiple issues in relation to the design and implementation of learning analytics solutions for complex technology-enhanced learning ecosystems. For example, sustainable adoption of HCD approaches requires that researchers and teachers embrace design methods effectively, stakeholders should ideally be involved in the design at institutional levels, and there is a need to upskill the LA community in generative methods, design thinking, and co-design methodologies. A question that can immediately emerge as a response is: Is it worthy to deal with all the complexity and the resource-intensive process of human-centered design, i.e., co-design and participatory design, to create analytics aimed at supporting human decision-making? The short answer is yes. Although it may initially seem that collaborative design sessions may be time-consuming, in the long term, the benefits of co-creating effective tools that address authentic challenges can reduce costs and offer much more value than trying to force the integration of poorly designed analytics into current practices. Sanders and Stappers (2008) explained how design approaches solely based on observing how users work cannot address the scale or the complexity of the challenges we face today. HCD methods are thus expected to become increasingly critical for designing LA systems to be embedded in the increasingly complex technology-enhanced learning ecosystems we have today. HCD methods can also help researchers, practitioners, and designers in keeping a balance between technical aspects and human factors in LA. For example, co-designing with teachers can contribute to increasing teachers' agency as designers by considering their beliefs, attitudes, preferences, and knowledge. It can also enhance the technology, pedagogy, and content knowledge of teachers toward better orchestration and redesign and ultimately balance the role of the artificial intelligence and the human agents, toward an eventual augmentation of teachers and students. Although more empirical research is still needed to provide maturity to human-centered approaches in LA, the two studies described in this chapter are aimed at providing confidence in the potential benefits of involving critical stakeholders in the design process of LA systems to improve teaching and learning.

Against the two approaches illustrated through the studies presented above, we envisage future empirical work will aim at understanding how we can move toward explainable learning analytics (e.g., using data storytelling principles from the human-computer interaction and data science fields), instead of asking for an enhanced data literacy of the users for them to be able to interact with learning analytics solutions (Verbert et al., 2020). More work is also needed to identify what needs to be the right balance between orchestration and learning design aspects being embedded into the LA tool (embedded analytics) versus creating orchestrable learning analytics that can more freely be used by teachers according to their design intentions. Finally, we do hope that the discussion in this chapter may contribute to some maturity of the human-centered design perspective for learning analytics solutions.

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Index

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