DESIGN AND DEVELOPMENT OF LEARNING OBJECTS FOR LOWER SECONDARY EDUCATION IN GREECE: THE CASE OF COMPUTER SCIENCE E-BOOKS[1]

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Abstract

This paper reports on the design framework and the development of a variety of learning objects aiming at the enrichment of both, the lower secondary education computer science e-textbooks and the Greek National Aggregator of Educational Content. At first, the theoretical foundations and critical instructional design issues for computer science learning objects are addressed. The learning objects design and development method is also presented. Following, indicative examples of learning objects are presented and their affordances to support active, inquiry and constructivist learning activities in school practice are discussed. Conclusions for educational practice and further research in the schools are drawn.

Keywords: e-books, learning objects, ICT, computer science education, mental models

1 INTRODUCTION

Information and Communications Technologies (ICT) have been widely perceived as the agent of educational changes and major innovations in school practice that would lead to significant educational and pedagogical outcomes and support students' development on the knowledge and skills needed to succeed in the 21st century society. In the past decade, the nature of the Web and the way people access and use Web recourses for personal, educational, employment, entertainment and other social purposes, have been fundamentally changed. Browser is becoming the universal interface to a range of new Web tools and media storing applications. The use of Web tools for learning purposes is expected to exert a significant impact on education and the way people learn by changing the relationship between instruction and learning, inquiry and knowledge construction, and the boundaries between classroom and homework activities.

Academics, researchers, educators and policy makers have advocated that the emerged Web based tools and applications have the potential to offer enhanced learning opportunities for students and educators. Consequently, major changes are expected in the way educational materials are designed, developed, and delivered to people, both students and adults, interested to learn. Current technological and pedagogical developments regarding the educational applications of ICT have led to increased interest about the development of electronic books (Kay & Knaack, 2008a; Nelson, 2008). E-books are digital format textbooks, enriched with multimedia and digital content, simulations, various resources, interactive applications, learning scenarios, problems and exercises etc. In recent years, e-books are considered as a promising idea for the integration of ICT in education offering opportunities to extend learning spaces beyond the boarders of traditional classrooms.

Web based learning object systems include various tools designed to support teaching and learning by helping students to explore, share, build and apply their knowledge. The development and the integration of learning objects into classroom practice has been dynamically evolved in recent years, in various educational contexts ranging from primary (Lim, Song & Lee, 2011) and secondary education (Baki & Cakiroglu, 2010; Lowe et al., 2010; Kay & Knaack, 2008a; 2008b) to university level as well (Lam, Lam & McNaught, 2009).

This paper presents the main outcomes of a developmental project concerning the construction of learning objects and their integration into computer science e-textbooks for lower secondary education (K7-K9) in Greece. The project was implemented in the framework of Digital School (2010) programme, an ambitious national and EU funded programme, which was administered by the

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Computer Technology Institute and Press "Diophantus", under the aegis of the Greek Ministry of Education. The article is structured as follows. The first section addresses both theoretical foundations and instructional design issues regarding the design and development method followed. After this, indicative examples of learning objects embedded into the Computer Science e-books and the Photodentro (2013), the Greek National Aggregator of Educational Content, are given and proposed to support students' learning activities and classroom practices. Conclusions are drawn for educational practice and further research in the area.

2 LITERATURE REVIEW

2.1 From e-textbooks to Learning Object Repositories

Digital textbooks or e-books are widely defined as interactive web-based tools that support learning in a specific domain by enhancing, amplifying, and guiding learners' cognitive and learning activities. Therefore, e-books are not just a digital version (pdf or html) of a conventional printed material. An electronic book changes the nature of the traditional textbook and the ways it is used by both, students and teachers, in classroom and personal learning activities. The digital elements included in e-textbooks are described as Learning Objects (LO) which incorporate features such as hyperlinks, multimedia, interactivity and search ability. LO are expected to enhance the potential of ICT in the next generation of instructional design, development, and delivery, due to their features of *reusability*, *interoperability*, *adaptability* and *scalability* (Willey, 2000).

Grounded in the object-oriented paradigm of computer science, learning objects are elements of a new type of web-based tools for instruction and learning, which are based on the notion of small, self-contained and reusable units of learning (Agostinho et al., 2004; Duval et al., 2004; Polsani, 2003; Wiley, 2000). The fundamental idea behind learning objects is that instructional designers can build small (in relation to the size of an entire course) instructional components that can be reused in different learning contexts. Additionally, learning objects are generally understood to be digital artefacts deliverable through Web, allowing any number of people to access and use them simultaneously. Properly designed LO have clear objectives and learning goals with a narrow focus, thus helping tutors to develop effective lesson plans and integration strategies.

A learning object is composed of two related components: the *object content* and its *metadata.* Metadata include descriptive information about the characteristics of the resource contained in the particular LO, helpful for searching, finding, managing, using and reusing LO effectively. This is the main distinguishing feature of LO from other digital tools, which enables cataloguing and searching LO through web based repositories, e.g. collections that can be searched with standardized metadata.

2.2 Photodentro: the Greek Digital Learning Object Repository

Photodentro (2013) is the Greek Digital Learning Object Repository for primary and secondary education. It has been designed and developed in the framework of Digital School (2010), an ambitious developmental programme aiming at the integration of ICT in the Greek educational system, which was funded by EU and the Greek government. Photodentro is connected to the Digital School Educational Platform thus facilitating teachers and students in finding educational material and using it in learning scenarios and courses.

Photodentro platform is more than a repository of reusable LO. It includes LO related to the various subjects across the curriculum, e.g. Greek and foreign languages, mathematics, science, social sciences, computer science etc. Moreover, Photodentro constitutes the *Greek National Aggregator of Educational Content* accumulating metadata from collections of digital resources that are stored in digital libraries and repositories of other organizations (museums, libraries, audiovisual archives, etc.) and which can be exploited in the learning process.

Photodentro stores reusable learning objects that have been developed by teachers in the context of the enrichment of primary and secondary education textbooks or have been created in the framework of previous projects funded by the Greek Ministry of Education or have been selected from other sources., with the aim to become the central repository of digital educational content open to all, students, teachers, parents and other people interested.

3 THE DESIGN FRAMEWORK

Current definitions of learning objects focus on flexibility, independence and reusability of content to offer a high degree of control to both, instructors and students. Therefore, the features inherent to LO have meaningfully connected the learning object approach to current instructional design theory. According to Kay (2012) two distinct categories of learning objects exist:

a) *Structured learning objects*, which typically deliver short sequences of information and then test students' knowledge or allow limited practice with the concepts to be learned.
b) *Open-ended learning objects*, which use a problem-based approach where students explore and test what-if scenarios to discover relationships and improve understanding of specific concepts.

Open-ended LO incorporate simulation, inquiry and other dynamic features aiming to offer a great variety of opportunities for constructivist learning and, therefore, they provide a bridge between students' prior knowledge and conceptual understanding through an active reformulation of their misconceptions (de Jong & Joolingen, 1998; Jimoyiannis & Komis, 2001; Vrachnos & Jimoyiannis, 2008). Current pedagogical trends suggested that learning is best supported when students are given the essential tools in an open-ended environment and required to personally and/or collaboratively construct understanding and knowledge. Kirschner et al. (2006) suggested a minimal level of instructional guidance, which is referred to by a variety of terms, including discovery, problem-based, inquiry and collaborative learning.

3.1 Basic components of a learning object

Developing efficient LO for learning is not only a technical matter; however, such systems should combine both modelling and instructional knowledge with a pedagogical strategy (Joolingen & de Jong, 2003). Therefore, a comprehensive learning model requires a great deal of mental and creative effort. Within the design framework described by Jimoyiannis (2008), there are three main components-building blocks of a LO (Fig. 1), which collectively define the knowledge body and how learning is approached or supported by this particular LO.

The learning scenario: Scenario related issues concern the conceptual focus of the LO, the concepts to be presented, the representational tools to be used (visual, simulation, modelling etc.) and the degree of model modification or model transparency incorporated. It is preferable the same model to be used by students at different educational levels, and students who have different skills, interests or educational needs. For example, the teacher may wish a model that could be simplified for novice users, allowing them to access a limited number of model variables, or to vary the degree to which students are allowed to view or manipulate the underlying model.

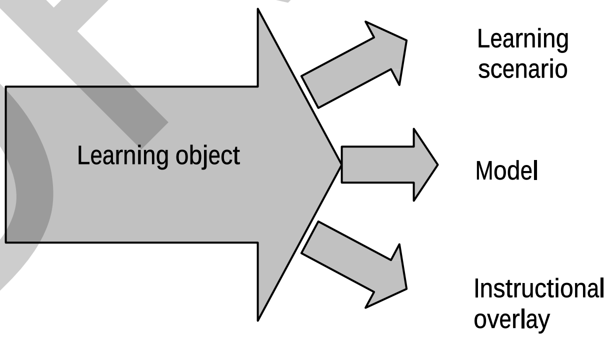

Fig. 1. The basic components of a learning object

The model: The model, upon which a LO is based, includes the various *presentations* of the target system and the *functionality* (user actions, feedback, operational features). Usually, the model is simplified to some degree in order to facilitate learning. Such a simplification is necessary because, by increasing complexity, increases the time required by students to understand the LO and so does the likelihood that they will become frustrated or demotivated. For example, by reducing simulation realism, the designer can clarify complex or difficult concepts and can tailor the LO to the students' prior knowledge and experience.

The instructional overlay: The third component of a LO, the instructional overlay, is determined by those features defining the educational context and the representational forms used, the pedagogical approach (discovery, inquiry learning or collaborative knowledge construction), the type of tasks it supports and, finally, learner motivation, guidance, assistance and feedback. A well-designed instructional overlay can: a) prompt and motivate students, b) incorporate guidance aiming to direct students towards learning goals, c) focus students' attention upon important learning aspects of the LO, and d) progressively unfold the complexity of a LO over a series of stages in order to reduce students' cognitive overloading.

4 METHODOLOGY AND TOOLS

Teaching computer science and programming to lower secondary education students constitutes a very interesting task with particular difficulties in relation to the other subjects in the Curriculum. Students' difficulties in algorithmic thinking and using programming constructs for problem solving are well-known and documented in the literature. The key point is that, in computer science students need to think about problems, algorithms and data in ways that are quite different to those in other domains and in regular classroom learning activities (Komis & Jimoyiannis, 2006).

The design method and the approach used in creating LO for the lower secondary (K7-K9) computer science e-books was guided by

- The new National Curriculum for ICT and Computer Science Literacy and its philosophy which directs classroom activities and practices; e.g. ICT is considered as a cognitive-learning tool, promoting students' research, creativity, collaboration, modeling and problem solving.
- The research findings of computer science education which concern a) students' misconceptions about basic computer science concepts and difficulties the faced at when they solve problems using programming environments and general purpose tools, and b) the specific instructional barriers teachers are facing in introductory courses.

A consistent working framework was adopted and used to support collaborative construction of the learning objects. Fig. 2 shows the main interrelated phases which determined, more or less, both individual and group work towards the creation of each particular specific LO.

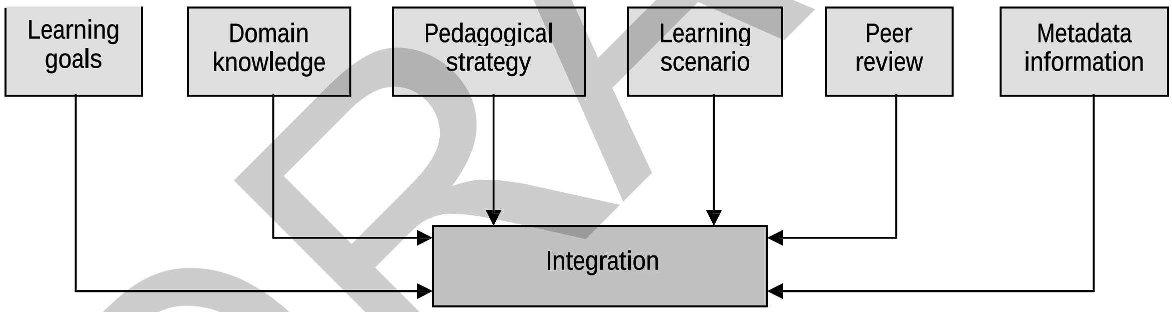

Fig. 2. Learning object development phases

4.1 The development group

The project of the design and development of the computer science e-textbooks and learning objects started on February 2011. The first author was the coordinator of the development group. He is currently a member of the National Curriculum Board. Twelve highly experienced computer science teachers with extended experience as developers were initially selected, after an open call. Their studies and degrees, teaching experience in secondary education schools and in developmental ICT projects were the basic selection criteria. In the second phase of the project (September 2011-today), six of them (the other authors) remained actively involved into the project.

4.2 Process and tools

The innovative aspect of this project was that the members of the development group were working collaboratively and implemented their project tasks remotely. An open source platform was used to support members' personal and group work during the project. The system provided personal tools (e.g. personal file repository, online profile, RSS reader etc.), communication tools (e.g. forum, chat, direct e-mail access etc.) and group functionalities within the community (e.g. file and content sharing area, wiki, creating and managing groups, product repository etc.).

The project members were asked to use the platform as the principal communication, discussion, collaboration, selection, storage and co-creation environment. They were asked to share files, information, recourses and ideas in order to collaboratively define learning goals and areas of interest, to describe main ideas for the development of learning objects, to design and create LO, to review and evaluate peer artefacts and, finally, to improve and integrate their products in the e-textbooks, according to the objectives of the Computer Science Curriculum. Successive versions of LO were continually uploaded into the platform and peer commented, in order to make adjustments and corrections, to improve the quality and create the final form included in the repository. In addition, the developers exchanged ideas about metadata information used to describe the content, the technological and the instructional dimensions of the LO included in the repository (Photodentro, 2013).

Communication, peer feedback, interaction, ideas interchanging, criticism, extending and synthesis of ideas, collaboration and material sharing by group members were, basically, implemented through the project platform. In the working period (February 2011- February 2013), a total of 91 discussion themes were emerged within the platform and 2420 messages were present. Fig. 3 shows a screenshot of the platform, displaying the file sharing area and the workflow of teachers' developmental activities. Other technologies were also used to support project activities in a complementary way, like BigBlueButton web conferencing system, Skype, and e-mail.

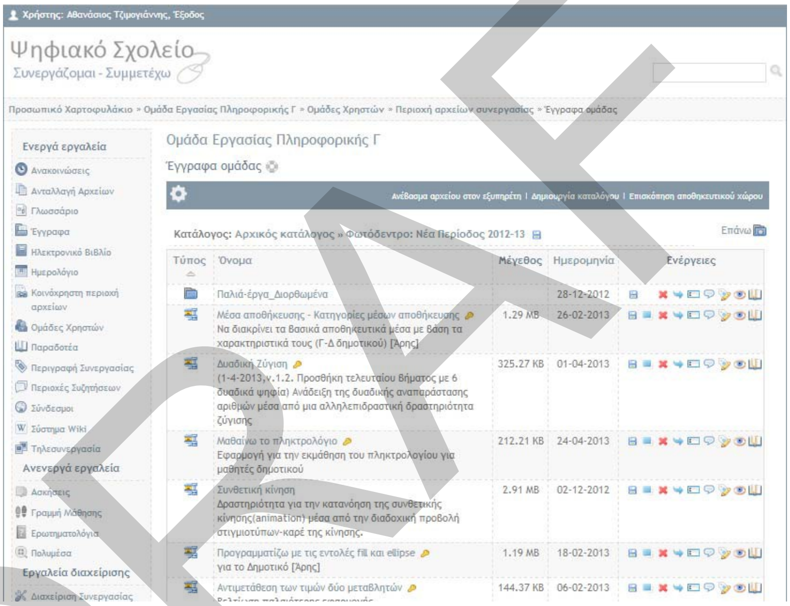

Fig. 3. A screenshot of the development platform

5 PROJECT OUTCOMES AND LEARNING OBJECTS CREATED

A total of 157 learning objects were finally included in the computer science e-textbooks and the Photodentro repository, along with the related metadata information. Basically, they were innovative digital artefacts of four main types, e.g. visualisations, micro-activities, interactive micro-lessons and open-ended applications. Three main technological formats were used: Java applets, Flash applications and Captivate video. Table 1 summarizes the various LO in relation to the computer science e-books of the three grades (K7-K9). Links to external recourses (e.g. Wikipedia, educational portals, the Greek educational TV etc.) were also included in the e-textbooks.

Table 1. Classification of the computer science learning objects

Learning object	7^{th} grade	8^{th} grade	9^{th} grade
Visualisations-presentations	13	10	16
Micro-activities	12	22	12
Micro-lessons	19	30	9
Open-ended applications	2	7	5
Total	**46**	**69**	**42**

5.1 Visualisations-presentations

Visualisations are interactive, structured learning objects, which present chunks of multimedia information regarding computer science concepts and analyse content knowledge directly related to the student paper textbook (e.g. hardware, software, information coding and representation, programming concepts etc.). Fig. 4 shows two screenshots of a Flash application presenting the evolution of the digital storage media (http://photodentro.edu.gr/jspui/handle/8521/959).

Fig. 4. Screenshots of an interactive presentation of the storage media

5.2 Micro-activities

The learning object presented in Fig. 5 is a micro-activity aiming at students' familiarization with bitmap graphics and helping them to construct efficient mental representations of the pixel concept (http://photodentro.edu.gr/jspui/handle/8521/741). It is a Java applet which includes a series of default bitmap graphics (e.g. cross, chess table, target, smile, character A) in a grid of 8x8 elements. Students are able to experiment with the representation in the grid and change the bit values in order to construct their own bitmap picture. Buttons like 'bit reversing', 'clearing screen', and 'full screen view' aim to improve the functionality and the interactivity features of this particular LO.

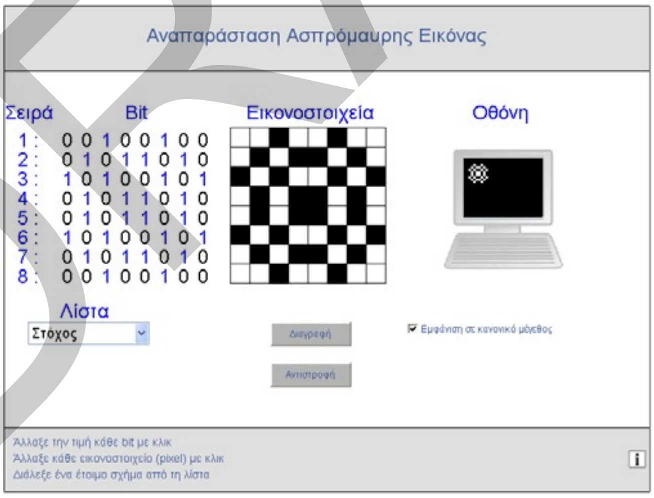

Fig. 5. A screenshot of the micro-activity 'picture representation'

5.3 Micro-lessons

Micro-lessons are interactive videos which support a short task or a complete activity, using general purpose software (e.g. editor, spreadsheet, presentation) or programming environments (e.g. Logo, Scratch). Fig. 6 shows two screenshots of a micro-lesson about graph construction using spreadsheet software. This LO can be found at http://photodentro.edu.gr/jspui/handle/8521/624. The application dynamically addresses the critical operations in spreadsheet software, in order to construct graphs in various formats, e.g. column, bar, line, pie etc. Students have the opportunity to experiment with the successive creation steps, to go back and forward, to try various graph formats etc., in order to enhance their skills and capabilities. They can see their results on the screen and repeat the procedure as many times as they wish. Finally, the students can be asked to transfer this or a similar activity in a real spreadsheet environment.

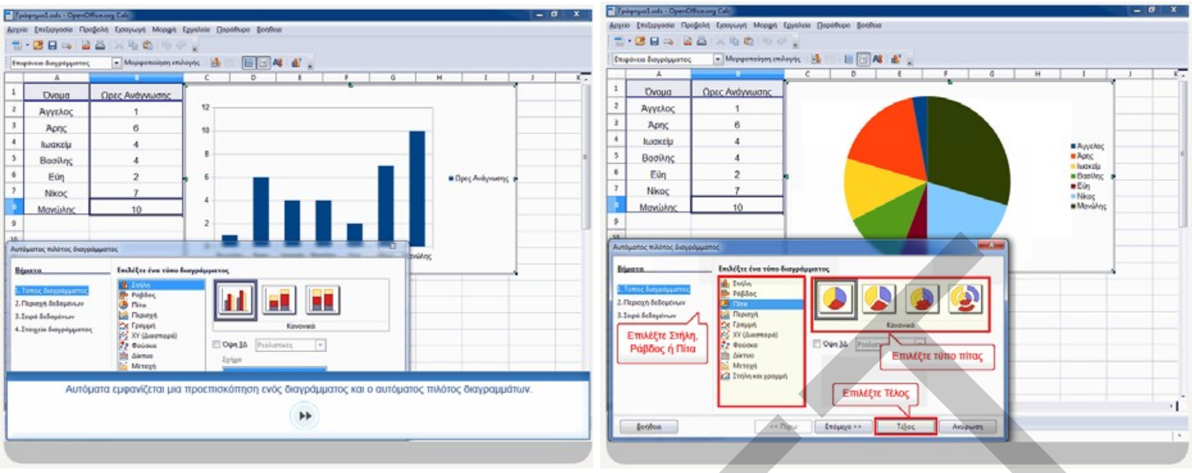

Fig. 6. Screenshots of a spreadsheet micro-lesson about graph construction

5.4 Open-ended applications

In Fig. 7, we show screenshots of an open-ended application entitled *'Drawing with simple Logo commands'* (http://photodentro.edu.gr/jspui/handle/8521/615). Using a small set of dynamic features, this LO application can help students to familiarize with a Logo-like programming environment and support the development of algorithmic thinking skills. The application includes eight default Logo programs drawing simple geometric shapes (cycle, triangle, rectangular, octagon, house and star). Students are able to use these programs, to make changes and see the result on the screen. Moreover, they can write their own Logo programs. The application incorporates a range of functionalities and operations, like program start, step-by-step execution, back step, reset, help etc.

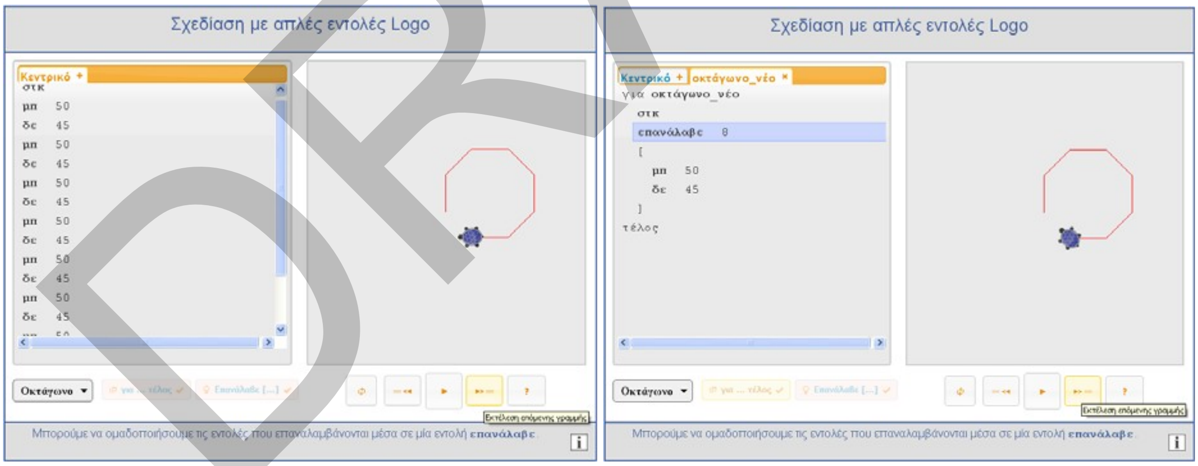

Fig. 7. A screenshot of the dynamic Logo application

The innovative feature of this LO is that the students are able to select a set of commands and the system can dynamically transform them into a loop or a procedure (see Fig. 7). Overall, this application incorporates a series of affordances that offer enhanced opportunities to the teachers to design constructivist activities aiming a) to promote students' participation and active learning in introductory programming lessons and b) to support students' construction of effectual representations and mental models regarding programming concepts and notions (e.g. loops, procedures etc.).

6 EPILOGUE

Electronic textbooks and the Greek National Aggregator of Educational Content are now available for schools, students and teachers, shaping a new environment for the Greek educational system. In particular, as far as the subject of ICT and computer science it concerns, there is a variety of applications and learning objects which offer enhanced opportunities for new instructional strategies in lower secondary schools. On the other hand, the new National Curriculum has determined an integrated framework in order that the students, after completing compulsory education (K-9), have the opportunity to develop the necessary digital competence (knowledge, skills and attitudes) for their participation in the knowledge society. However, the systematic use of LO in computer science classrooms needs time and continuous efforts, in order to effectively influence students' development. Computer science teachers are the agent for the successful integration of the new e-books and computer science LO in everyday practice. Their appropriate preparation and pedagogical support could help teachers to reorganize their teaching by using new pedagogical strategies aiming at students' active participation, content exploration, experimentation, inquiry, and finally, construction of new knowledge about ICT, computer science and programming.

Undoubtedly, there are still many issues open to clarify, once learning objects been understood by both, teachers and students, and be integrated in current classroom and learning practices. For example, what are teachers' attitudes towards using computer science LO in their instruction? What are students' attitudes towards using LO to implement learning activities? What types of LO are effective and what educational practices around LO are feasible in school practice? How could we promote and enhance students' engagement and performance when using specific LO for learning? These could be some indicative questions for future research aiming to respond to the new challenges for researching LO-based practices and pedagogy in the Greek schools.

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