Empowering Teachers in Challenging times for Science and Environmental Education: Uses for scenarios and microworlds as boundary objects

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Abstract:

Science education has been going through a process of change and transition through continual questioning of both its practice and the involved teacher pedagogies. The opportunities provided by the integration of digital technologies and the arguments for extending science teaching and learning processes towards addressing more socio-environmental issues, create new expectations with regards to the role of the science teacher. Teacher education needs to contribute to preparing science teachers to respond to these on-going challenges. In this paper we articulate the rationale and analyse the technique we employed in a training course for science teacher educators to empower them to redefine their roles as 'co-designers' and 'co-discussants' of innovations based on the integration of digital technologies in school science education. Our approach consists of designing sets of paired artefacts ('scenarios' and 'half-baked microworlds') to play the role of 'boundary objects' with the aim to facilitate meaning-generation processes among science teachers by means of continuous boundary-crossing. We suggest that processes of this kind can have a 'bridging' function not only among different communities within science education but also between science education and environmental education, whose epistemology and pedagogy could greatly benefit current science education to reform towards more socially-oriented and interdisciplinary approaches to meaningfully understanding reality.

Keywords: science education, environmental education, teacher training, scenarios, microworlds, boundary objects

Introduction

Since as far back as the sixties science education has been going through a process of change and transition through continual questioning of both its practice and the involved teacher pedagogies (Osborne & Dillon, 2010). Developments in terms of approaching science per se, defining what constitutes ‘appropriate’ scientific knowledge for compulsory education, understanding how learning evolves in relation to various types of knowledge, and adjusting curriculum accordingly, have triggered discussion about pedagogy in science education and created changing expectations with regards to the role of the science teacher. Science teacher education was affected accordingly both at the pre-service and the in-service level.

Among the developments that have considerably altered the view and practice of current science education is the potential for the use of digital technologies for added pedagogical value, and the arguments for extending science teaching and learning processes from the basic concepts and ideas of science towards more meaningful and socially-oriented approaches to understanding issues of the current socio-environmental reality (Dillon & Scott, 2002). As suggested by Dillon and Manning (2010) these new developments and innovations in science education “need to be understood by science teachers if they are to keep abreast of their subject’s place in the curriculum” (p. 13). Science teachers’ education, both at the pre-service and the in-service level, should contribute significantly to this direction by preparing teachers to be able to respond to the on-going challenges to their profession and take over the expected new roles (Supovitz & Turner, 2000). However, what kinds of design and methods for teacher education can facilitate such deep changes in science teachers as professionals so that they become integral members of this continual development? In this paper we discuss issues which we saw as pertinent for the design of a course to train science teacher educators to induce reform in classroom practice based on added value uses of digital media. The course was part of a longitudinal systemic initiative to generate uses of digital technologies in primary and secondary edcation in Greece.

As part of this initiative, the Greek Ministry of Education funded a nation-wide project engaging University-based centres to prepare teacher educators who would subsequently provide 96 hours-courses to colleagues with the objective to integrate digital technology in their subject teaching. The case discussed in this paper involved the training of a group of five experienced science teachers. These teachers participated in a 350 hours-course designed to address the domains of physics, chemistry, biology, geography and environmental education so that they could then act as teacher educators for other science teachers. The course started in May 2011 and lasted until February 2012. It took place at the Educational Technology Lab (ETL) in the School of Philosophy at the University of Athens.

In this paper we discuss the approach we took to design the science teachers' training. Our main concern was to avoid simply splitting up the course into the constituent objectives of technical, pedagogical and domain knowledge in a fragmented way. Instead, we wanted to perceive these teachers as agents of a profession 'under challenge' and to play a role in empowering them to generate a life-long learning culture in their future courses with their colleagues. This was a result of both a tradition in training teacher educators in other subjects at ETL (Kynigos, 2001) and of our reflections on a relevant design approach for science education. Our course design aimed to engage them in a quest for empowering their colleagues to meet the challenges posed by the questioning of epistemologies in science and in pedagogy, the realization of issues of relevance in science content causing the students' disenchantment with science, and the frequently poorly defined authoritarian requests for reform with problematic support for its implementation. We saw our role as facilitators for them to cross their 'boundaries' both at a pedagogical and an epistemological level. Namely, our aim was to empower them to become creative designers of pedagogical interventions and generators of reflection in school practitioners through exploring innovative uses of the digital technologies in the teaching of science. We also aimed to encourage them to consider the potential of opening their repertoire of taught topics to more real-life and socially relevant issues and their pedagogies to interdisciplinary fields of study, such is the case of environmental education, and by doing this, to re-address the role of science, that of science education and their related cultures.

Teaching and learning with digital technologies for added pedagogical value in science

Learning about science involves developing an understanding of the scientific content, i.e. the concepts and formal relationships of how the world works, and the scientific approach to inquiry, both of which are not easy for students to grasp. Furthermore, the phenomenological characteristics of the discipline give central stage to the students' experiences with the physical world which often lead to deeply ingrained misconceptions with respect to the concepts, relations and behaviors inherent in these phenomena (diSessa, 1982, 1983; Vosniadou & Brewer, 1992). In science education, models and modeling play a significant role in challenging students' undertandings of difficult concepts and relationships and in familiarizing them with scientific approaches of inquiry in the study of abstract, complex phenomena of the physical world (Dede, Salzman, Loftin, & Sprague, 1999; diSessa, 2000; Squire, Barnett, Grant &

Higginbotham, 2004). Digital models embody important added value to this learning process since they afford limitless experimentation, a wealth of representations, measurements temporally connected with the modelled phenomenon, extension of the range of phenomena which can be modelled, including the 'impossible' ("how hard do I kick a ball to send it beyond the Earth's gravitational pull?"), the 'expensive' ("when does gold melt?"), the 'dangerous' (i.e., chemical reactions), etc. They also afford experimentations with abstract phenomena or situations involving societal issues (such as in SimCity-like games).

Models can play the role of tools with which students can question scientific rules and relations, become engineers of models themselves and engage in 'what if' questions involving the nature and specifics of these rules (Kynigos, 2007; Kynigos, Yiannoutsou, Alexopoulou & Kontogiannis, 2006; Sherin, 2001). Such activity with digital media enables the students to get 'immersed' into worlds whose behaviour is either according or against the established scientific laws and principles (Smyrnaiou, Moustaki & Kynigos, 2011). For instance, digital microworlds can be designed to represent a physical world that works based on the Newtonian laws or allow students to experiment with and alter these laws. They can even go up to defining new rules upon which to base the function of an unreal or imaginary reality. The students can therefore not only get involved into learning experiences through which they can better understand the scientific models having been offered by acknowledged scientists to explain the world. They can even become scientists themselves and attempt to creatively construct and test their own models by drawing upon previous scientific content knowledge and using their intuitive thinking to interpret and construct new realities within an appropriately constructed microworld environment (Healy & Kynigos, 2010).

By being supported to represent scientific concepts, relationships and phenomena with the use of digital games teachers can trigger the students' motivation to understand them and at the same time foster deeper and more critical learning with regards to science (Gee, 2003; Squire et al., 2004). The same applies also to the students' inquiry skills (Cuevas, Lee, Hart, Deaktor, 2005; Lee, 2002) and modeling competences (Smyrnaiou & Dimitracopoulou, 2007; Smyrnaiou & Weil-Barais, 2005) which can be also developed with the use of digital tools. What is anticipated is that by following processes similar to those of formal scientific inquiry, students will address the problems under study more deeply and they will consequently learn both the content of scientific knowledge and the method of scientific knowledge building.

Expanding the scope of science education towards encapsulating a socio-environmental education perspective

Among the key debates in science education is that one questioning the traditional paradigm of focusing exclusively on scientific concepts and ideas as isolated from the broader phenomena and social contexts in which they become relevant, and without highlighting the relevance and value of this knowledge to the students' life and society in general. Within this paradigm, science education seems to reproduce the false myth of science as objective and value-free discipline (Osborne, 2000), which by consequence makes it appear alienated from current reality and the challenging issues and dilemmas societies are confronted with. Criticisms of this genre are supported by evidence from many countries indicating that school curricula give preponderant emphasis on foundationalist approaches of learning about science, science content over process and pedagogies advancing the transmission of dry ‘scientific facts’ (Hacker & Rowe, 1997), as if all students were being prepared to become the scientists of tomorrow. However, there are serious doubts about whether such science curricula can succeed to trigger in students any meaningful engagements with science (Dillon & Scott, 2002; Osborne & Collins, 2000; Osborne, Driver & Simon, 1996).

Actually, quite a few recent studies document a widespread lack of student interest in school science education (Dekkers & De Laeter 1997; Sjøberg & Schreiner 2005; Gough, 2007; Littledyke, 2008). Many students worldwide abstain from considering scientific knowledge as capable of meaningfully explaining current reality and as relevant both to the society and to them personally. Research evidence is supported by the decreasing numbers in student enrolments and student participation in science courses. Instead, several studies ascertain a growing interest among students of all levels in issues involving societal and environmental concerns (Chatzifotiou, Liarakou & Daskolia, 2006; Daskolia, Flogaitis, Liarakou, 2007; Daskolia, Flogaitis & Papageorgiou, 2006; Flogaitis, Daskolia, Chatzifotiou & Liarakou, 2005) and in educational practices that allow them to develop meaningful understandings of the world (Gough, 2005; Gough & Sharpley, 2005). A suggestion so that current science education becomes appropriate and meaningful to a wider range of students is to ‘bridge’ it with educational domains which are more socially-oriented and centred to real-life problems, such is the case of environmental education (Dillon & Scott, 2002).

The opportunities for developing a beneficial relationship between science education and environmental education have been identified by many scholars. Gough (2002, 2007) argues that science education has to gain a lot in motivating students to get more actively involved with science content if it turns to address some of the most challenging socio-scientific and sustainability issues which are also relevant to the students' interests. The experience gained from the international ROSE research project (http://roseproject.no) confirms this assertion (Sjøberg & Schreiner, 2005). Environmental and sustainability issues can be treated as learning themes from which to draw and study several concepts and aspects of the science curriculum. By opening to a new agenda of topics which are more personally appealing to students, science education can retain the students' interest while also redirecting its school practice to address real-life problems. At the same time it becomes more relevant to societal needs by contributing to the creation of a scientifically literate citizenry, better equipped to ensure environmental sustainability (Fensham, 1978; Gough, 2007; Lucas, 1980).

Furthermore, science education can benefit a lot from the conceptual and methodological richness of environmental education and the application of multiple perspectives in studying reality, to challenge disciplinary orthodoxies and deeply-rooted myths of science as the one and only, objective and value-free field of knowledge. Like any other social practice and its products, science is a socially and culturally situated activity (Delia, 1977) and so is all teaching and learning processes addressing scientific knowledge. By recognising that there are some social, moral, and political underpinnings in our understanding of the 'science' component of any current environmental and sustainability issue and that various conflicting interests intervene when applying, interpreting and 'using' scientific knowledge in addressing these issues, it is an important advancement for science education (Dillon & Scott, 2002). On the other hand, environmental education can gain from its relationship with a reformed science education curriculum by widening its realms towards scientific knowledge and how to incorporate it into all processes of understanding and dealing with current environmental realities (Hodson, 2002; Littledyke, 2008), and by being challenged to reconsider its long-standing critical stance towards the role of science in environmental discourse (Hajer, 1995).

This debate is also inherent in the Greek academic science and environmental education community discourse, although not yet explicitly articulated in systemic or local initiatives of curricular change. What is also evident is that, internationally and in Greece, the very act of reforming the school curriculum to become better attuned to the specifications of a more socially-oriented and environmentally-focused science education has a number of barriers to transcend. Among those are the dominant culture of science teaching, the traditional norms of school practice and the teachers' inappropriate preparation to respond to the demands of this new role (Osborne, 2000). In designing this training course we thus felt it was pertinent to invite Greek science teachers to engage with this debate and contribute to communicating it to their colleagues.

In search of appropriate teacher education frameworks for teaching science with digital technologies

Among the factors that inhibit the effective integration of digital technologies in classroom teaching and learning is that of teacher professional development. In our view, this situation cannot be adequately addressed by attributing failure to rigid teacher mindsets and practices nor to the specifics of professional development courses. We see such problems as symptoms of a lack of general culture, societal and institutional, concerning the profile of the teacher profession. Training courses cannot assume authoritarian stances aiming to just fill in what their designers presume as ‘holes’ in the teachers’ competency or knowledge. In our view, they need to engage teachers in emergent communities of practice affording them the role of ‘co-discussants and co-designers of reform’ in participatory contexts where teacher educators facilitate, inspire and challenge mutually growing ideas and practices (Kynigos, 2007).

Seen through this lens, one of the shorcomings of competence-based teacher training courses could be identified in their preponderance mainly at improving the teachers’ technology competency levels with the implicit aim that this will automatically lead to more lasting changes in teaching and learning processes and finally to a restructuring of the existing curriculum. However, these interventions have a rather limited scope. Teaching a disciplinary field of knowldge is a fairly complex process in itself, as teachers need to combine knowledge of the subject-matter with pedagogical knowledge to be able to teach effectively in a classroom-based context. The potential of integrating technology in teaching a subject has added one more challenge to teachers, how to successfully combine technological knowledge with pedagogical and content knowledge. This task becomes even more complicated from the fact that there is no “one best way” to integrate technology into the curriculum (Koehler & Mishra, 2009).

If fundamental changes are to be put forward on an educational level, new approaches to professional development have to be sought for (Watson, 2001). Although our understanding of what constitutes ‘appropriate‘knowledge’ for the teachers to meaningfully and effectively get engaged with the use of digital technologies in the teaching of their subject domain is still growing, there are some theoretical models already present in the literature that merit our attention. One of them which we found useful is the Technological Pedagogical Content Knowledge (TPCK) framework (Koehler & Mishra 2008; Mishra & Koehler 2006; Koehler & Mishra 2009; Mishra, Koehler & Kereluik 2009), a theoretical model poposed for conceptualizing teachers' professional knowledge base needed for integrating digital technologies into teaching practice.

TPCK is based on Shulman's (1986) model of Pedagogical Content Knowledge (PCK). However, it expands it towards incorporating technology as an equal constituent part of the teachers' knowledge base and builds on new constructs arising from the interplays between content knowledge, pedagogy knowledge, and technology knowledge. (Figure 1 provides a representation of the TPCK framework).

Insert Figure 1 about here

TPCK foresees three new types of knowledge which are generated in the intersections of the three circles in Figure 1: pedagogical content knowledge, technological content knowledge, and technological pedagogical knowledge. Pedagogical Content Knowledge (PCK) is the amalgam of content knowledge and pedagogy needed for teachers to consider how to teach their particular subject-matter. Technological Content Knowledge (TCK) refers to understanding how the subject-matter (or the types of representations that are built on it) is transformed from the use of technology, and to developing the criteria on which to decide about the appropriateness of tools. Technological Pedagogical Knowledge (TPK) refers to knowledge about the pedagogical affordances and constraints of a variety of technological tools within the context of particular pedagogical designs and strategies.

However, what lies at the heart of the teachers' technological literacy is a fourth new type of knowledge that comes from the interaction between content knowledge, pedagogical knowledge, and technology knowledge. This is 'technological pedagogical content knowledge' (TPCK) which encapsulates according to Koehler & Mishra (2008) the essence of the teachers' competence of teaching with digital technologies. In other words, it denotes that a teacher is capable of interpreting how these three domains of knowledge interrelate and that s/he is ready to respond with flexibility to any particular learning situation s/he faces every time s/he teaches.

The model by Koehler & Mishra (2008) emphasises the interactive and relational nature of teacher knowledge which encompasses content, pedagogy and technology. It furthermore suggests that intelligent pedagogical uses of technology require the development of complex and situated forms of knowledge.

So, in designing our course, we used this background as a base to think of the kinds of issues around which our trainee educators would be interested in discussing and gaining expertise. However, we addressed participants as members of a professional community that require empowerment with respect to the role assigned to them by the educational system and society at large and the responsibility and initiative this may carry on their part. We thus negotiated a norm of 'co-design' and 'co-formation' of this systemic reform where they themselves would join us in various types of design and would subsequently invite their collegues to create their own designs. It is through this activity of design and development of educational artefacts and activity plans that we endeavoured to generate reflection and community work around TPCK issues. We thought of two specific artefacts to engage science teachers in: a) mutually negotiated activity plans which we call 'scenarios' and b) questionable and malleable digital artefacts which we call ‘half-baked microworlds’ (Kynigos, 2007). In fact we saw these artefacts as pairs, each unit of curriculum design as being consisted of a scenario accompanied by a half-baked microworld.

Using scenarios and half-baked microworlds as boundary objects

The concept of ‘boundary object’ was originally coined by Star and Griesemer (1989) to define entities (of an abstract or concrete form) which are at the same time ‘plastic’ enough to be interpreted and employed by two or more communities in ways that make sense to them, and ‘robust’ enough to manifest a common identity across all communities. Although loosely structured in shared use, boundary objects acquire specific meanings and functions within the context of each community. What is of prime importance is that by being commonly recognised by the various intersecting actors, boundary objects can ensure coherence and promote collaboration amongst the communities involved (Wenger, 1998) as well as foster negotiation across them (Lee, 2007). By this process they enable the ‘crossing of boundaries’ (Suchman, 1994) within and amongst the communities involved and their respective practices and cultures.

In a teacher education context, we perceive ‘scenarios’ and ‘half-baked microwrolds’ as artefacts that can play the role of ‘boundary objects’ in cases where they are purposefully designed and employed by teacher educators as to facilitate meaning-generation processes among learners (prospective or in-service teachers) by means of continuous boundary crossing (Kynigos & Kalogeria, in press). A rather generic use of the term ‘scenario’ in the context of teaching and learning with digital technologies is centred around the idea of a written document which delineates with as much precision as possible a situation where a learning intervention is either envisaged or might be required to be designed and implemented with the aim to meet specific educational needs. In some cases the concept of 'scenario' is also used to denote a description of the intervention itself or is identified with a (teaching or lesson) plan which results from an explicit effort to address specific educational needs. In any case, a 'scenario' can be defined as a conceptual artefact providing detailed description of a 'way' to reach specific educational goals for a given population of learners. The word 'way' covers a variety of aspects including not only the activity to be implemented and how it will be socially orchestrated, but also the pedagogical/epistemological framework within which it is based, plans of the activity, a description of the digital and other resources required and of the setting in which learning will take place.

The author of a scenario (be it a teacher or a teacher educator or a researcher) is asked to explicitly recognize and address aspects of the learning situation that is to be designed based on the use of digital technologies, which are pedagogically pertinent. Such aspects are the ways in which s/he expects participants in a learning situation to approach concepts and issues of the subject-matter through the use of particular digital tools, how they envisage learning through this use, how they anticipate the social orchestration of the activity in terms of timing, number and synthesis of the groups of learners, what types of outcomes are expected to be produced by them, kinds of digital representations and the ways in which they are foreseen to be manipulated, and more. Scenarios also refer to the added educational value of the planned activity, to the nature of the innovation and to the learning problems it may address.

Within the context of this training course we approached 'scenarios' as artefacts constructed to be employed in the following modes of use:

- as training resourses created by the researchers/ trainers to be used by the participants within the context of the training course,
- as activity plans meant to be developed or adapted by the course participants to be used by them within the context of their teacher training or classroom practice,
- as 'boundary objects', that is artefacts especially designed by the researchers/ trainers to assist the course participants to get engaged in collaborative design, reflection and discussion on alternative choices with regards to matters of science content, pedagogy and use of technology, as well as the underlying norms of each choice.

In the present paper we focus on the third use of scenarios as 'boundary objects'. To this end, scenarios are viewed as malleable, questionable and improvable objects by design, in the sense that they call teachers to challenge them, change them and adapt them to their theories and practical needs. By becoming objects of discussion, negotiation and shared understanding amongst teachers and their trainers on issues of subject-matter, pedagogy and technology, scenarios induce the crossing of boundaries from all parts. At the same time, they fulfil a 'bridging' function by bringing together both communities and domains of knowledge and helping them borrow from each other.

Our second type of boundary objects, 'half-baked microworlds', are defined and mediated as digital artefacts also purposefully designed to be used by participants in a learning situation (Kynigos, 2007). They are also characterized as incomplete or buggy and are given to learners to study their behavior, look for bugs or unsatisfactory features and change them. In doing so, they will notice properties, relations, concepts with which these artefacts operate. They are expected to do this in groups, negotiate meanings and actions and also come up with collective productions. By being characterized as questionable, malleable and improvable objects, microworlds can also operate as boundary objects, and so they did within the context of our training course with the science teacher educators.

Examples of scenarios and microworlds used in the teacher training course

In designing the training course we gave a key role to the engagement of the science teachers either with the design of scenarios and microworlds from scratch or with the use of ones we had specially designed for them to de-construct and make changes to. We viewed each of the participants as actors within the boundaries of both their disciplinary community and their teacher practitioner community. Our course design aimed to encourage and facilitate them to cross these boundaries in order to communicate with the academic community and participate in the structuring of a 'new' teacher educator community. Namely, our pedagogical perspective was to engage them in processes of challenging the boundaries of each of these communities through discussion and actions of re-constructing scenarios and microworlds at hand. For example, one of the learning situations the teachers were provided for in the course was when they were asked to enact the scenarios designed by the researchers/ trainers by them taking the role of the students. Following that, they were asked to jointly address aspects of the learning situation that were pedagogically, technologically and content pertinent to them and to think subsequently as learners, teachers, and teacher educators. In doing so, they were able to notice and discuss contradictions to their practice and reflect on their ways of thinking about science content and science education. They were also allowed to fully question the scenarios and microworlds and make changes in them according to mutually agreed criteria.

In Appendix A and Appendix B we outline two scenarios which were purposefully designed by us to be implemented by participants in the training course as starting points. The first scenario (Appendix A) focuses on a physics phenomenon and the second (Appendix B) on a key environmental education concept, while each of them makes use of an appropriately designed domain-microworld. What they have in common is that they both attempt to 'transcend the borders' of established science education and bridge school practice with more meaningful and socially-oriented approaches to understanding current reality.

Some concluding remarks

In this paper we aimed to contribute to the discussion of instructional design principles and methods for reform-based interventions involving added value uses of digital technologies in science education. Our design aimed to integrate a) the pedagogical challenges of addressing conceptual difficulties and relevance-related shortcomings of current school science practice leading to students' disenchantment with it, with b) teacher education challenges of empowering a teaching profession under challenge. The method we conceived to apply was that of facilitating various types of 'boundary-crossings' with view to generate changes in the ways science teacher educators and science teachers perceive their roles. Our pedagogical intention was to empower them to re-define their roles as 'co-designers' and 'co-discussants' of innovations based on the integration of digital media in school science education. By viewing teachers in teacher education contexts as representatives of different communities and sub-cultures our aim as academic trainers was to enable them first to identify their 'boundaries' in terms of their own content, pedagogical and technological knowledge and then to support them in crossing these boundaries. As the course developed, our reflections on these design principles enhanced our view that we need to better understand this process by shedding more light to the challenges the teachers face and the changes they have to undergo when asked to transcend boundaries of this kind, both in their subject domain and teaching practice.

In this paper we articulated the rationale and analyzed the technique we employed in training course for science teacher educators, which is that of designing artefacts to play the role of 'boundary objects' in facilitating teachers in boundary-crossing processes. We suggest that artefacts such as scenarios and microworlds can potentially fulfil a 'bridging' function not only amongst science teachers from different communities (trainees, practitioners, teacher educators) or disciplinary cultures (i.e. physicists, chemists, biologists, etc), but also between science education and other educational domains. This is particularly pertinent with environmental education, an educational domain whose epistemology and pedagogy could greatly benefit current science education to reform towards more socially-oriented and interdisciplinary approaches to meaningfully understanding reality. However, more research is needed to shed light into the processes with which these techniques are put to use. We are about to complete the collection of data from various activities we designed and conducted within the context of this training course. Our next step is to submit these data into research analysis and critically discuss the findings in light of the proposed theoretical constructs we presented in this paper.

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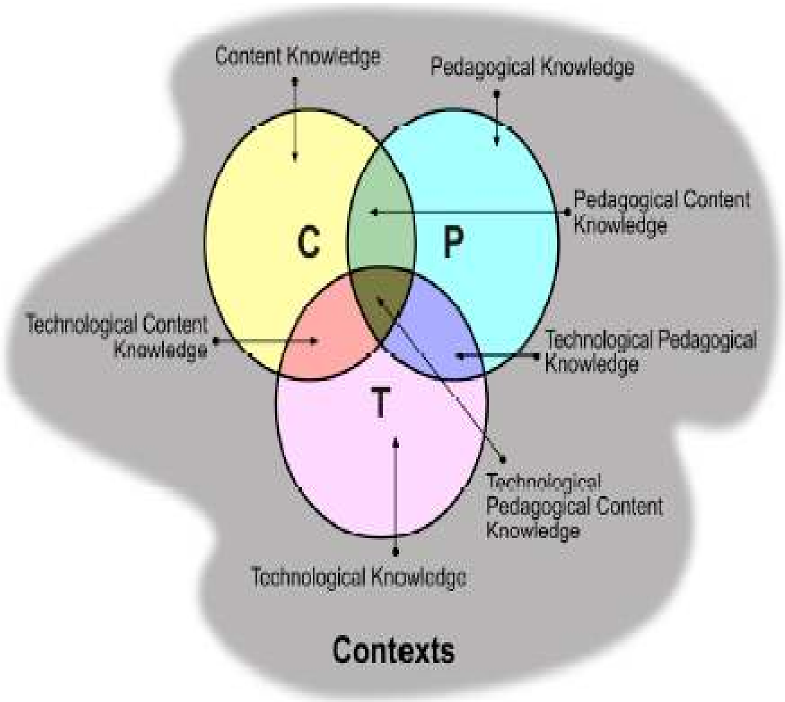

Figure 1. The TPACK model and its core components (Koehler & Mishra, 2008)

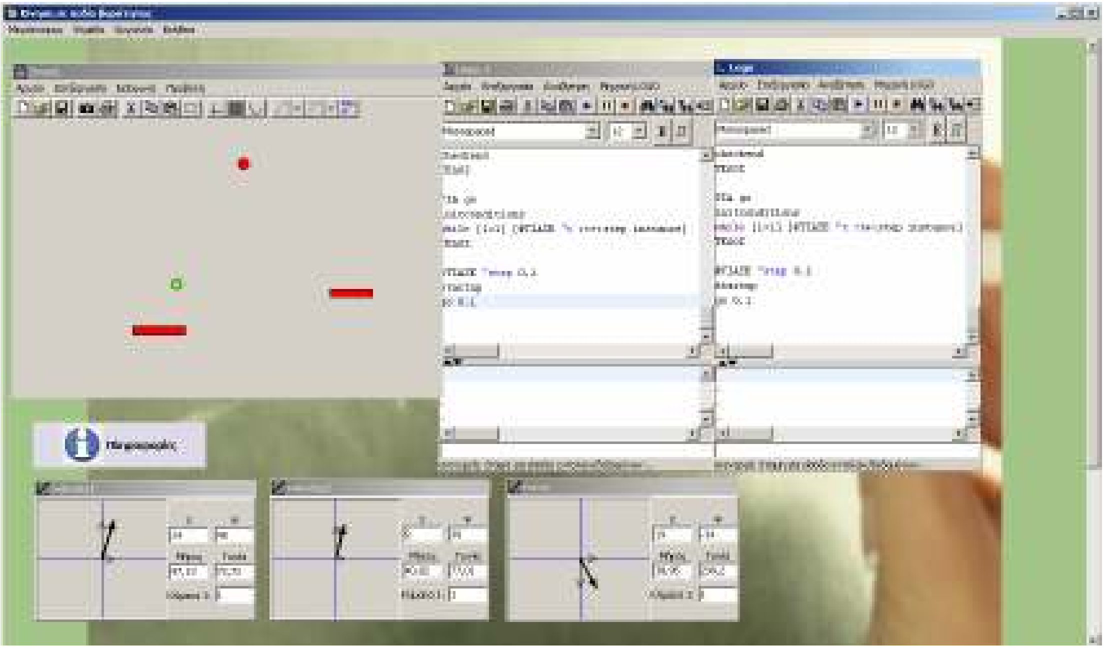

Figure 2: The ‘3d Juggler’ microworld

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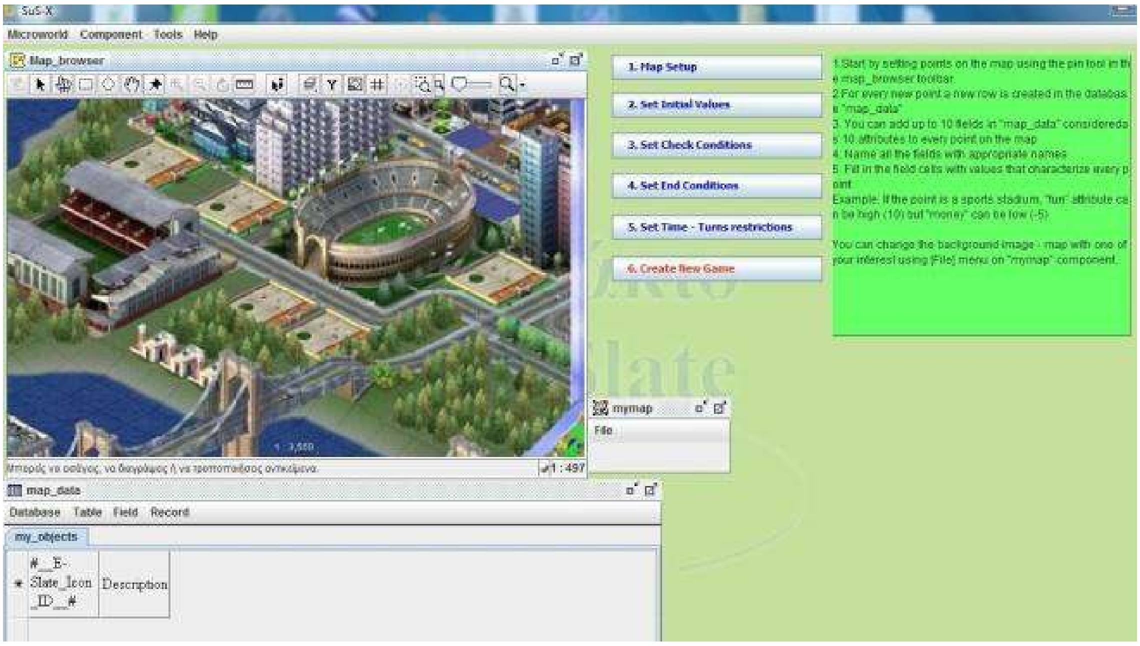

Figure 3: The ‘SusCity’ microworld

Appendix A

The physics scenario: 'The 3d Juggler'

This is a scenario developed to engage science teachers in addressing a classic physics topic, 'motion in 3d space', and some related concepts (the azimuth shot, the altitude shot, the wind direction, mass, velocity, forces, collision, etc.) through digital game play and design. The scenario is based on the use of the '3d Juggler' digital authoring system, a game microworld template that gives the users the possibility to insert objects and observe the simulation of phenomena every time they change the properties or behaviours of the objects by manipulating sliders or vectors. The users can also engage in Logo programming activities to change not only specific parameters of the existing model but the model itself. The added pedagogical value of the 3d Juggler microworld is that it allows users to create 3d game-like microworlds to simulate phenomena either defined by the Newtonian Laws (such as the basketball shooting game, the enemy shooting game) or not. The scenario aims to motivate and familiarise teachers (and students) with some innovative ways of using technology in teaching and learning processes centred on challenge-based issues and real-life phenomena, with view to make school science more relevant to the students' interests. Many teachers are reluctant to teach about issues of this kind because they are open to more than one explanation. The scenario foresees that the teachers and learners will play with a "3d Juggler" half-baked microworld as a starting point, in order to interact with the objects and their properties, the variables and formal equations which are embedded in this microworld. Later on, they are expected to work directly on the microworld, a fact that will give them the opportunity to act both as engineers and as scientists in trying to interpret concepts and formal equations, and at the same time to collaborate, argue, negotiate, and discuss with each other while exploring the microworld. Their final goal is to arrive at the construction of new game models by making use of the available functionalities of the microworld and by intervening directly on the game's underlying mechanism. In these new games the teachers have the opportunity to express their personal and collective representations of the concept of 'motion in 3d space'. Among the objectives of the proposed activity are to enable the teachers to critically reflect on new physics concepts and topics, realise the complexity of physical reality and discuss about the role of phenomenology in understanding it. Other objectives of the activity are to familiarise participants with the construction of digital games as boundary objects for teaching complex phenomena. The scenario foresees that the activity is implemented in 3 face-to-face training sessions of 5 hours each (an overall duration of 15 hours).

Insert Figure 2 about here

Appendix B

The environmental education scenario: 'From PerfectVille to MySusCity'

The general idea behind the environmental education scenario is to involve the science teachers in addressing some core concepts of the current environmental discourse (those of 'sustainability', 'quality of life', 'sustainable lifestyles', 'sustainable urban living', etc) through digital game play and design. More particularly, the scenario aims to engage teachers in dealing with the complex and systemic nature of their everyday activities as well as with identifying and critically approaching the sustainability parameters of human practices within the urban environment. Participants are expected first to play "PerfectVille", a half-baked game microworld which was deliberately built by the researchers/ teacher educators on some contested 'axioms' about what sustainable living in a city means (Kynigos & Daskolia, 2011). By playing the game the teachers are expected to challenge these axioms and get engaged in discussion, negotiation and argumentation processes about how they define 'sustainability' and in which practices of their everyday life they identify it. This discussion is to be used as a new conceptual basis on which the teachers would then be called to design a new game by employing the SusCity game microworld template. SusCity is a digital authoring system for SimCity-like games which leaves open to user manipulation, construction and de-construction the part of the mechanism that contains the 'model of sustainability' upon which the game is built, while keeping away the syntax and the information that might be noise for the users. The users are therefore able to incorporate their own sustainability criteria in the new games they create. The added pedagogical value of the SusCity microworld is that it allows teachers (and students) to integrate 'a sustainability model' in the digital game they construct as opposed to just discussing a theoretical model. They can also evaluate and further reflect on this model during game play which is a motivating activity oriented towards examining how the model works. Among the objectives of the proposed activity are to enable the teachers to critically examine some core sustainability concepts, understand the multi-faceted character of certain sustainability issues and explore alternative frames of viewing them in relation to their everyday practices that support unsustainable ways of living in the city. Other objectives of the activity are to familiarise teachers with the construction of digital games as boundary objects for teaching and learning complex concepts. The scenario foresees that the activity is implemented in 2 face-to-face training sessions of 5 hours each (an overall duration of 10 hours).

Insert Figure 3 about here