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Teachers' Development Regarding Cognitive Schemas and Creativity Through the Design of Digital Learning Tools

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Abstract

Science teaching has become closely related with the concept of creativity which is embedded in the learning process with the implementation of activities that enhance students' engagement in the design, experimentation and inquiry of the scientific concepts under negotiation. However, there is a research gap in terms of teachers' development of creative skills that would significantly contribute to their transferring and embedding this cognitive process into the learning process and teaching practices. In the present study we examine a teacher's development regarding cognitive schemas and creative skills while engaged in designing a learning tool that addresses the modular area of Kinematics. For the implementation of the design, there has been used the digital environment of E-slate as an authoring tool that allows for multiple creative experimentations. Our research findings result from tracking and thoroughly analyzing the designer's development regarding cognitive schemas and creativity while dynamically interacting with the authoring tool.

Keywords

Cognitive Schemes, Creativity, Inquiry-Based Approach, Instrumental Genesis

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1. Introduction

In recent years, science education has been dealing intensely with the concept of creativity. Creativity is approached and embedded in the learning process, via activities that allow students to design, test and investigate the given scientific problems. However, although the concept of creativity appears to be studied and applied in the pedagogical context of modern didactics, this integration is primarily oriented in the activity of students, failing to extend to its contribution in teacher development, considering cognitive aspects.

Taking into consideration the semiotic dimension of technological constructs, which emerges as the designer interacts with a given artefact during work activity, the present study focuses on the investigation of the assumption that the design and creation of digital constructs performed by teachers, contribute to his professional and scientific development. To explore this case, data were gathered and analyzed following the design course of a physics teacher, who attempted and completed the construction of a digital game for teaching science, without having any previous experience in designing. This procedure was realized with the use of the 'E-Slate' digital platform and 'Avakio 2' software. The design process of the final game, as it emerges from the teacher-designer's recordings in his planning journal and his saved efforts in each designing step, was analytically recorded by focusing mainly on aspects that concern the interaction between the artefact and the designer and the way this interaction contributed to the development of his pedagogical and technological cognitive schemes, as well as aspects that potentially reflect his in-depth immersion in the epistemology

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of his cognitive subject.

An interesting observation that emerged from the study of our data is the fact that the teacher evolved his pedagogical awareness by trying to incorporate new pedagogical techniques in the microworlds he constructed. Finally, together with the development of the teacher's technological and pedagogical schemes the designer was observed to undergo an in-depth reflection in the epistemology of his cognitive subject, as he was urged, through his interaction with the artifact, to study the curriculum and the specific scientific concepts that he wanted to teach. Consequently, the present research has led us to the conclusion that a teacher's engagement in the design process involves multifaceted levels of personal development regarding technology, pedagogy and cognitive reflection of the epistemology of the cognitive subject under negotiation.

2. Related Work

Open authoring tools provide a dynamic space for teachers in the role of designers to orchestrate their learning goals and creatively realize their representation while manipulating mediating artefacts [1, 2]. The design process is not a linear procedure but allows for multiple entries and exploitations regarding methodologies, pedagogical approaches and techniques, creative challenges that lead to the designer's cognitive development [3, 4]. The dynamic nature of the design process in triggering the designer's emergence of cognitive schemes and creative skills lies in the dialogic space that is established between the designer and the tool [5, 6]. The designer's intervention on the tool transforms them to entities [7] and environments for both creative constructionism and reflection [3]. The constructionist element embedded in these authoring environments regarding their inquiry structure or semiotic representation of scientific concepts [8, 9, 10, 11] provides the basis for deep access to cognitive areas which emerge according to the designer's reaction and personal perception while interacting with these environments. This way the designer is enhanced to construct his own operational invariants (concepts-in-action and theorems-in-action) and meaningful representations [12, 13]. This bilateral relation is grounded on the concept of instrumental genesis which addresses two simultaneous functions: (1) the evolution of the artifact as the designer's activity unfolds, and (2) the construction of systems that will facilitate the utilization of the artifacts [3]. According to Trouche [14] (fig. 1), two different processes are realized between the tool and the subject; each one with a different starting point. The process of instrumentation that is oriented towards subject (subject-oriented) and the process of 'instrumentilization' that is orientated towards the artifact (artifact-oriented) [15]. It is basically a process that involves activation towards two categories of schemes: schemes oriented to the management of the tool (usage schemes) and instrumented schemes of instrumented action (action schemes) with a focus on the activity itself [14]. The tool as the mediator of the action is conducive to the designer's awareness of cognitively informed next design steps, regarding technological affordances of the tool and his development of technological skills, implementation of pedagogical approaches that comply with the semiotic representations embedded in the tool [16, 7] and the potential for emergence of new cognitive schemes [17]. In the tool -designer interaction there is a continuous juxtaposition between the designer's cognitive available resources and the limits and affordances of the tool. In other words, the construction of the artefact relies on the dual process of constant feedback deriving from the tool and the continuous reflective skepticism of the designer. While the designer is engaged in the design process, he applies himself inquiry skills in his effort to manipulate the visualization of the scientific concepts under negotiation, their experimental procedure, analysis and interpretation [16]. Through this inquiry-based design process, the designer's reflective mechanisms are triggered [18] and enable the evaluation of the efficiency of the artefact. As a result the tool transforms from a primitive prototype to a scientifically sound construct which projects its designer's cognitive development and creativity.

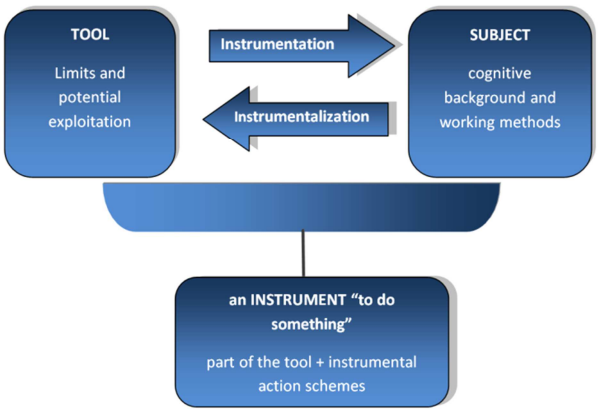

Fig. 1. Instrumental genesis as a combination of two processes: (1) through subject's individual activity, (2) through teacher's organized activity (Trouche, 2004:289).

Many Research studies have been conducted on the contribution of digital technologies in the enhancement of creativity and its significance regarding the learning process [19, 20]. However, there is a research gap in terms of teachers' development of creative skills through the use of ICT. Educators need to become aware of the need and the way to possess creative capabilities in order to be able to transfer and embed this process of cognitive development into the teaching process and practices [21, 22]. The Pedagogy to address

creativity lies on the ability to "design learning experiences and spaces which allow incubation, generation and analysis" [5, 6]. This identification of the design element as key contributor in addressing creativity requires further research on exploring the most suitable contexts for its realization. The context that digital technologies provide for development in creativity, accommodating interaction and provisionality as key elements, is mostly contributing since it lies on the meaningful, purposeful intervention of human agency [23, 24, 25]. The design process regarding an open authoring tool with an embedded inquiry approach inevitably leads to high levels of cognitive engagement and development of creative skills [3]. An authoring tool that is grounded on the principles of constructionim by engaging the designer in hands-on activities and in-depth reflection of the consequences of his design decisions requires and urges for alternative perceptions and cognitively informed decisions.

3. Study Design and Methodology

To study the role of creativity in teacher's cognitive development a physics teacher was requested to design and create a microworld as a learning tool that would focus on a specific scientific thematic area of physics. The physics teacher possessed basic pedagogical and technological skills as she was a postgraduate student of the "Digital Technologies in Education" MA course of the Pedagogical department of the National and Kapodistrian University of Athens. However, she lacked experience in designing and programming software. The design phase was conducted at the Educational Technology Lab of the NKUA (http://etl.ppp.uoa.gr/index.htm).

For the implementation of the design, the teacher used the digital environment of E-slate (http://etl.ppp.uoa.gr/_content/download/index_download_en.htm), with the negotiation of scientific concepts as the main axis. The platform provides a design environment, theoretically grounded on the principles of constructionism and affords functionalities that enable the designer to creatively experiment. The platform's creative aspect lies on its operating structure which allows alternative connections and programming of individual components enabling the designer to create his own microworlds or use functionalities from existing ones in order to experiment, test and understand scientific relations and assumptions [26].

The research study lasted about 3 months until the designer was able to complete the construction of a microworld that would effectively reflect the required learning goals she had set. During the study 20 microworlds were produced all of which negotiating the same cognitive module of Kinematics.

The theoretical aspects underpinning this research study are grounded on the theoretical construct of instrumental genesis [14], and the semiotic dimension of technological constructs, which emerges in the interaction of the designer with the artifact during work activity. In alignment with the above theoretical aspects the designer was asked to store each of her planning efforts (successful or not) and record each attempt at a planning calendar. Thus, our study was based on the data gathered with the help of this planning calendar as well as the stored microworlds reflecting every design step. Each of the 20 artifacts constituted a unit of analysis on the basis of recording the entire process. All the microworlds were grouped and examined on the basis of their Time Sequence in three temporal stages (initial stage, middle stage, completion stage) which enabled us to register and examine the designer's sequential activation through the cognitive schemas and creativity filters. Each stage reflects the designer's creative evolution of cognitive schemas together with the adoption of a set of educational approaches. More specifically, our research components were established through the categorization of the designer's cognitive schemas into three key areas (technological and emerging cognitive schemas and creativity, pedagogical and emerging cognitive schemas creativity and those relating to the epistemology of physics). During the design process, we track and follow the designer's cognitive process, while dealing with the projection of the cognitive content and manipulating the technical functions (quantitative and qualitative) of the computing environment, as well as his interpretation for the specific transitions from one procedural level to another.

4. Analysis and Results

During this design process, the E-SLATE platform is exploited, which is a source of pre-manufactured educational software, as well as an authoring system and a system of secondary software development. Analytically, the design experimentation in the initial microworlds involves adaptations of existing elements from a template microworld which is oriented towards the negotiation of scientific concepts. However, the initial microworlds evolve with entries of original orders into their codes as well as additions of components which constitute a figment of the inquiry-based interaction between the designer's cognitive resources and the technical affordances and response of the open authoring environment. For the sake of economy, we have decided to present the analysis of three microworlds; each one typical of the temporal stage to which they belong.

4.1. Initial Design-Stage

During the initial design phase, the designer is actively engaged in cognitive processes involving the understanding of

the platform's operability in order to proceed with his own design plans. The designer spends time experimenting and tinkering with the existing Eslate microworld kits provided in the platform in her effort to understand the connection between the functionality of the components and the logo programming language.

The designer's interaction with the digital tool triggers the designer's involvement in a cognitive inquiry. Although the designer had already decided on producing a digital learning tool that would negotiate the cognitive module of Kinematics and Dynamics of Physics, being influenced by the affordances of the learning tool she reflects on the difficulties that students face in understanding diagrams and their connection with the representing scientific concept and decides to embed this aspect as a learning goal in her own artefact. The dialogic space between the designer and the digital tool has led to the former's cognitive in-depth reflection of the epistemology and didactics of physics as he is urged to identify scientific concepts that are confusing for students.

At this point in her initial and general plan to create a microworld negotiating the fundamental concepts of kinematics, more specific and new parameters emerge ("*I want to make a microworld that will help my students understand the basic concepts of speed, position, displacement, acceleration and be able to interpret the graphs relating to motion*").

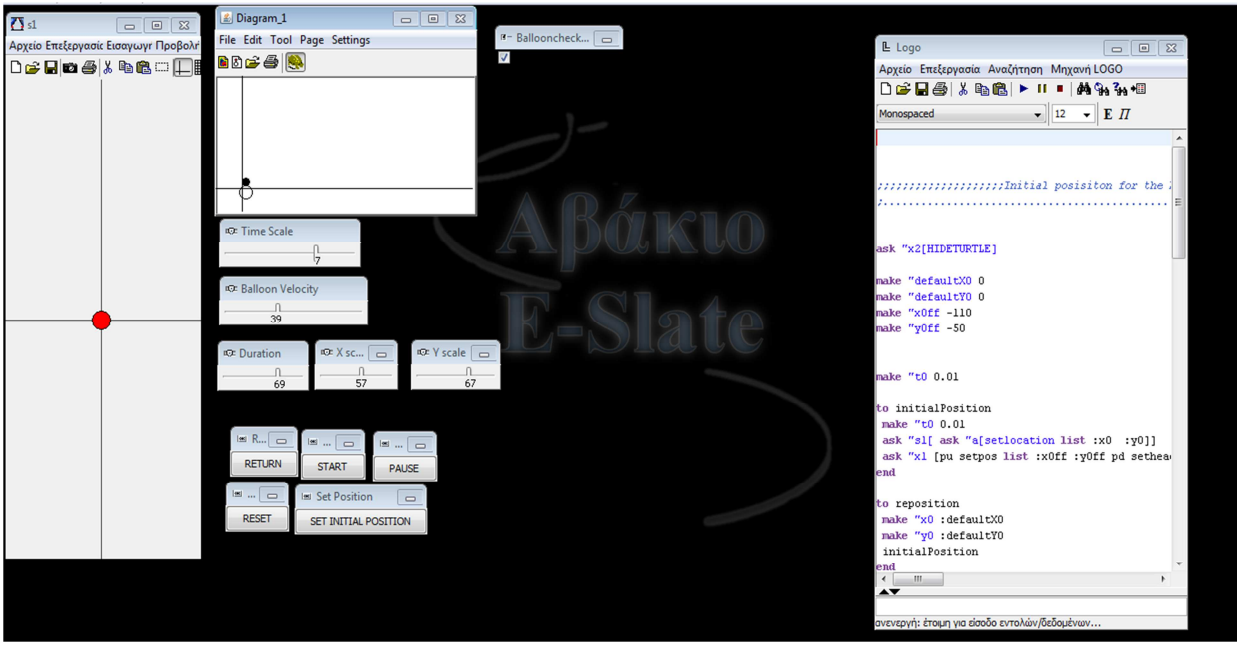

Fig. 2. Initial microworld based on existing templates.

Towards this goal she inserts components that project an object (red dot) performing linear smooth motion, speed-time and position-time graphs, a speed slider to enable students to regulate the object's movement, buttons to stop and restart the motion and a timer to register the duration of motion (fig 2). the inclusion of the above components as main functions of the learning tool are indicative of the pedagogical approach that the designer has adopted focusing on inquiry-based learning and experimentation on the part of the learners to check their hypotheses. However, the constructionist nature of the educational platform that is used, dynamically guides the designer to creatively project his conceptualised ideas, deriving from an in-depth reflection regarding the cognitive subject under negotiation.

4.2. Middle Design-Stage

During the middle design stage the designer in her effort to create a microworld that would successfully meet all the learning goals she had set, develops new cognitive schemas. At this stage she is not reduced to taking ready components and building blocks that the microworld kits provide but she cognitively progresses by registering and inserting logo code that she devises in order for her design to fulfil the pedagogical and didactical scope she had visualised (fig. 3). She inserts a Vector component which provides the ability to define and manage vector sizes in a straightforward manner and a turtle component that can trace the way and the degree of movement; in this case reflecting the position-time and speed-time graphs in alignment with the equations of motion of linear smooth motion (fig. 4). She also manages to expand the velocity slider range to cover both positive and negative values. This way the designer manages to fulfil the learning goals to encourage students to make logical correlations of the sizes involved in movement (eg. If the object arrives at the spot in four seconds, to travel half the distance in the same time speed needs to be doubled).

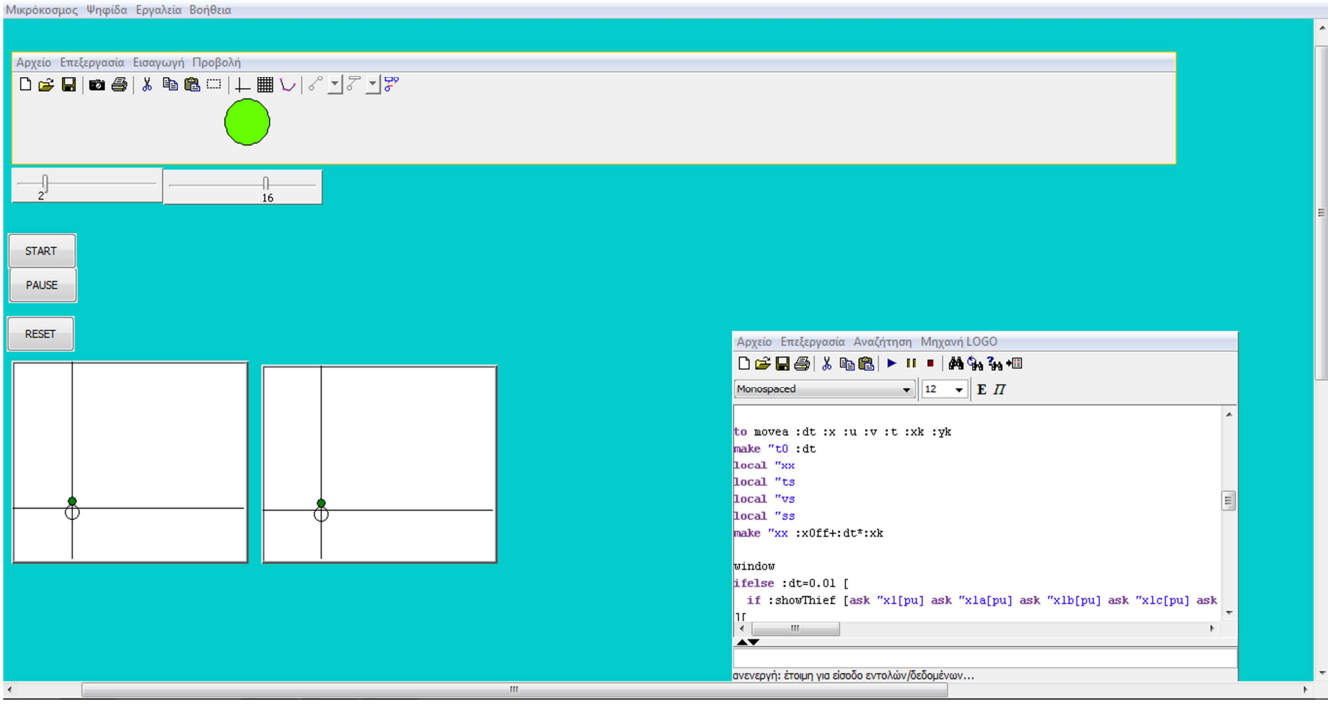

Fig. 3. Projection of the designer's reflection process – creating and inserting logo code.

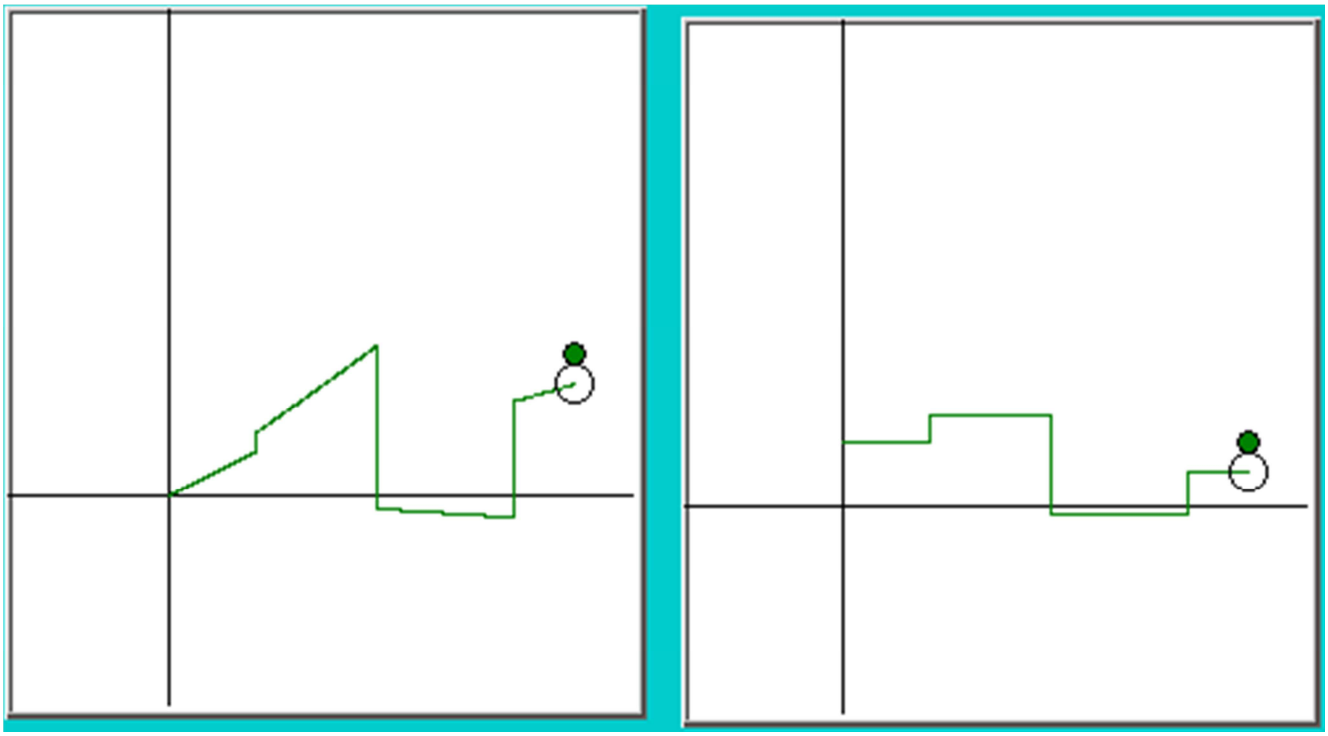

Fig. 4. Projection of the designer's reflection process – inserting a turtle component.

The addition of the components as well as the designer's cognitive expansion by creating his own logo code, are a result of her interaction with the digital tool. Instrumental genesis evolves through the designer's individual and organized activity and is projected through the creative manner that he manipulated the authoring tool. Undergoing a reflective inquiry, the designer becomes engaged in an in-depth search of the cognitive subject under negotiation but also the pedagogical aspects that she should consider to address her students' needs.

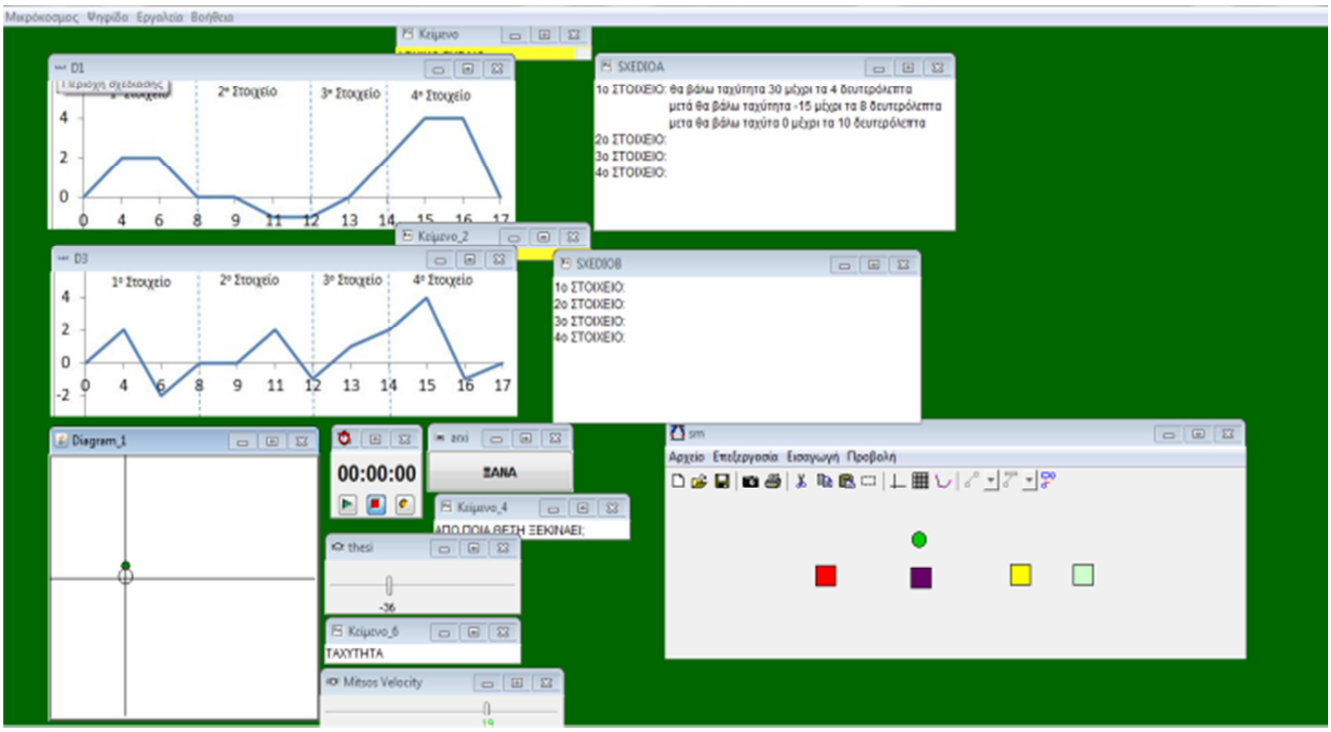

Fig. 5. The design of the second microworld with the addition of a second object.

5. Completion Design-Stage

The completion stage is characterised by high levels of creativity; the designer having acquired the logo code is now able to expand her artefact in a more pedagogically and didactically inclusive way. Reflecting again on the didactical aspects underpinning the cognitive subject of physics thinks of the problematic areas that students face in Kinematics and re-addresses her learning goals. She identifies the need for students to be able to interpret graphs of objects in motion but also to be able to link this thematic area with everyday real life situations. By identifying the students' need for acquiring a more holistic view of the phenomenon of motion she revisits the learning goals and comes up with the design of three interrelated and interconnected microwords contextualised in a playful and challenging story plot. The first microworld – already designed at the initial design stage will focus and test motion according to instructions presented in the form of a plot story. The second microworld will aim at the exploration of a motion graph, involving inquiry –based learning and collaboration; again contextualised and in relation to the plot stoy of the first microworld. Finally, the last microworld strongly linked to the principles of creativity and constructionism will urge the students to design their own game based on the creation of graphs and the interconnection between variables that are key elements in motion.

First, the designer inserts a second object and corresponding velocity and time sliders as well as turtle components and defines the equation movements according to which the two objects will move (fig. 5). The addition of the second object occurred by the designer's reflection of teaching problems and her search of pedagogical techniques that would help students during the learning process. In this phase the designer becomes concerned on pedagogical issues that the learning tool should address, considering the element of cooperation, development of metacognitive skills, reflection, self-assessment, inquiry-based teaching, engagement in challenging and creative tasks, etc. The designer is engaged in a creative and cognitive challenging process that will enable him to include effectively his pedagogical techniques and render her learning tool into a meaningful problem-solving task for her students.

Finally, the designer adds a data base and text components with appropriate logo code to accomplish the contextualisation of his learning tool (fig. 6). She creatively improvises the plot story of a witch, who wants to gather necessary ingredients to perform a spell youth. A text component will guide the students on information involving instructions on time and position of materials as well as the required speed for the students to set the witch in motion to gather the ingredients for the spell (fig. 7).

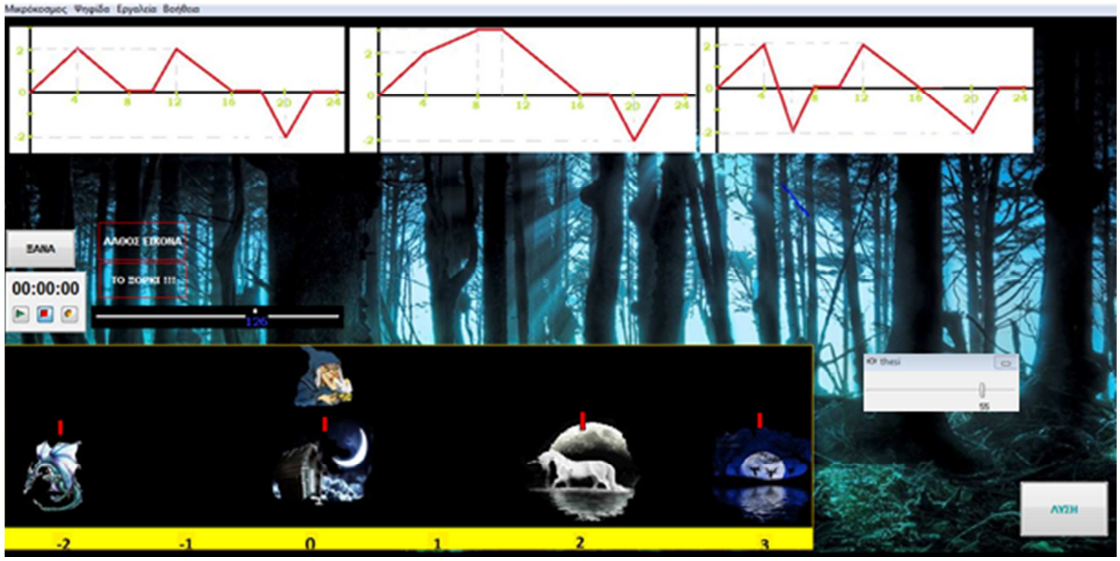

Fig. 6. Contextualisation of the learning process.

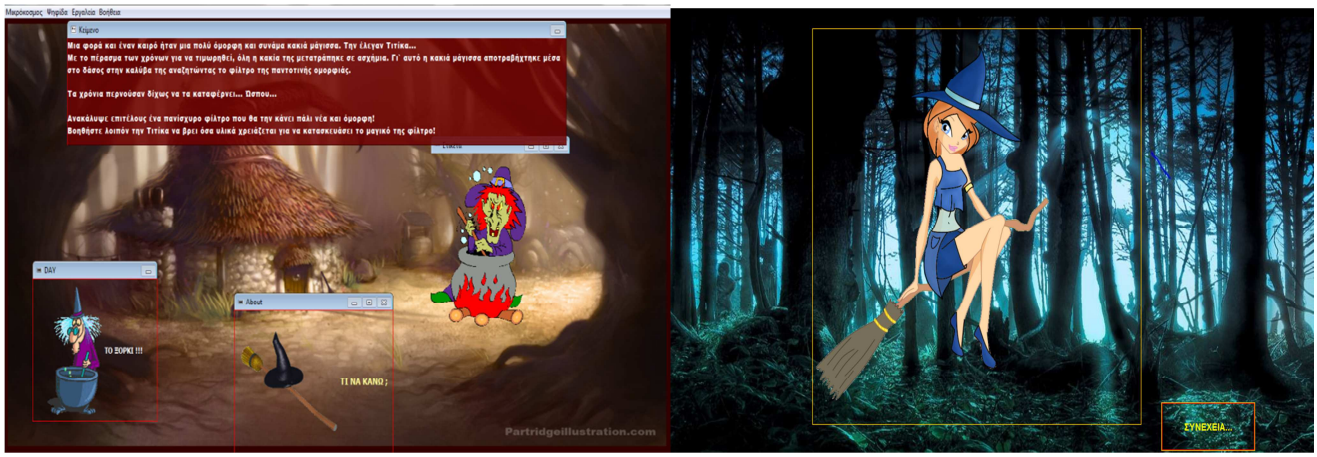

Fig. 7. The story plot underpinning the principles of Kinematics.

The digital platform becomes a canvas in the hands of the designer whose main aim at the final stage is to create the appropriate context that will engage the students in a challenging and motivating way to understand the scientific concepts that relate to Kinematics. Having structured and implemented in her design the holistic approach of the specific scientific concepts under negotiation, the designer becomes more creatively engaged in the pedagogical framing of her creation. Therefore, he embeds the element of game based-learning and sets the conditions for collaborative, problem-solving, inquiry-based learning.

6. Emerging Cognitive Schemas and Creativity

6.1. Designer's Technological Development

Analysing the microworlds - units of analysis, we track the designer's eminent cognitive evolution, concerning the use of design tools. At the initial design stage, the designer is cognitively restricted in taking ready components and embedding them in his own design. However, as stages progress she adopts a more active role in creatively designing by extending to the autonomous formation of a microworld with new code and suitably modified digital components.

It is therefore noticed a gradual and significant development regarding the technological skills acquired by the designer. The gradual evolution undergoes specific phases (testing, experimenting, tinkering, reflecting, improvising, creating) before the designer can move to a next evolutionary stage. A key attributor to the designer's development is the nature of interaction that the authoring tool accomodates. Its flexibility and intrinsic creativity urge the designer to experiment freely and revisit and reflect on the scientific concepts and the methodology of their embodiment. In addition, the efficiency

of the design environment is projected on the alternative manipulation of both quantitative and qualitative objects that it allows and its efficiency in setting a dynamic dialogic space.

6.2. Designer's Pedagogical Development

A cross- analysis of the temporal stages also reveals the designer's development regarding the selection and adaption of pedagogical approaches and techniques in the learning tool. Again the dialogic space established between the designer and the tool contributes to rendering the designer aware of the necessity for a pedagogical approach adoption. Initially, the designer seems to focus only on the scientific concepts that she has decided to teach; a tactic that seems to lack pedagogical concerns and relevant methodology. The designer's interaction with the tool and its pedagogical affordances which are embedded in it manage to shift and direct her focus to a more efficient and didactically inclusive approach. Towards the completion design stage, the designer obviously adopts a set of pedagogical techniques that dynamically reform the structure of her design. She creatively frames the learning tool with a playful context and revises the learning goals to include pedagogical parameters such as collaboration, development of metacognitive skills and self-assessment and peer-assessment.

It is therefore concluded that there is established a bilateral relation between the artefact and the designer that results in urging the latter to develop her pedagogical awareness and cognitively expand to a more pedagogically inclusive approach. In addition, the designer in his turn structures and reshapes the artefact in a way that it can efficiently support his pedagogical requirements.

6.3. Designer's Reflection on the Epistemology of Physics

During the designer's engagement with the construction of the microworld, she is urged to undergo an in-depth reflection regarding the epistemology of the cognitive subject under negotiation. This in-depth reflection is triggered on one hand from her need to embed and implement problematic areas of the thematic module under negotiation in the learning tool and on the other from the cognitive feedback that the artifact gives to the designer. The designer's reflection on the misconceptions that students have while addressing the particular scientific concepts also contributes to her development in creativity since she has to realize her revised learning goals while dealing with the affordances and limitations of the authoring tool.

As a result, the designer decides on creating three different microworlds aiming to enable students to actively engage and acquire a holistic view of the scientific concepts involved in Kinematics. All three microworlds are interconnected and interrelated with the inventive devise of a playful and challenging story plot which most creatively addresses the relevant with the learning goals scientific concepts.

7. Conclusions and Discussion

Our research study has revealed some important elements regarding the dynamics that are established between the designer and an authoring tool in terms of the development of cognitive schemas and creativity skills. This interaction is grounded on the establishment of a dialogic space between the designer and the artefact and the design process proceeds with the exploitation of symbolic forms. Until the realization of the final microworld, the designer proceeds from simpler cognitive and technological steps, such as the adjustments of readymade items from other microworlds to more sophisticated interventions such as registering original code and adding new components.

There is established a bilateral relation between the artefact and the designer that results in their evolution; the designer develops cognitive schemes and creative skills and the artefact expands and diversifies to meet the designer's needs. The dynamic nature of the computational environment lies on the establishment of dialogic space which empowers the design process. This empowerment involves the designer's engagement in an in-depth reflection of the cognitive concepts and the designer's urge for a holistic overview of the artefact and its embedded principles – pedagogical approaches, challenging nature, relation with the scientific inquiry, etc. In the E-slate authoring environment, the designer is enhanced to conceptualize the restructuring of the cognitive content as projected in the learning tool considering the tool's affordances and functionalities.

Analyzing in our research study the dynamics of this designer-artefact interaction during the design process regarding the designer's development of Cognitive schemas and Creativity skills, three key areas emerged as most prominently influenced and susceptible to reform: (1) the designer's technological development, (2) the designer's pedagogical development and (3) the designer's reflection on the epistemology of physics. The first axis involves the designer's cognitive evolution regarding the use of design tools. As the artefact evolves there is constant feedback that informs and urges the designer to adopt new strategies and creatively design new interventions that will finally re-structure and reform the artefact. Therefore, there is established a mutual informative relation that inevitably leads to creative and alternative design steps. The second axis refers to the designer becoming aware of the necessity for adopting and embedding pedagogical approaches in his artefact to accomplish its effective delivery. For the artefact to become an

efficient learning construct it should be grounded on relevant methodology and pedagogical approaches in order to fulfil its purpose and function in alignment with the defined learning goals. Finally, the designer's reflection on the core of the teaching concepts under negotiation and the epistemology of the cognitive subject occurs as an inevitable cognitive process that the designer undergoes due to his interaction with the tool. The visualization of the scientific concepts as projected on the tool leads to the emergence of multiple and alternative ways of representations. Such pluralism brings to the surface all kinds of cognitive skepticism from a holistic point of view (eg. fundamental principles of Kinematics, student's hands-on engagement with scientific concepts, etc.) to more fragmented didactical elements and problematic learning concepts (eg. students' difficulty in understanding motion graphs or relevant to motion variables, etc.).

Although the findings of this research study helped us to reach some primary conclusions regarding the cognitive processes and development that the designer undergoes while engaged in the design process, further investigation at a larger scale is required before we can reach some safe generalizations on the qualities of the designer-artefact interaction. In addition, it is also significant in a new research study to define the characteristics that an authoring tool should possess in order to facilitate the design of learning tools but also to contribute to the designer's development regarding cognitive schemas and creativity.

References

[1] Falconer, I., & Littlejohn, A. (2009). Representing Models of Practice. In L. Lockyer, S. Bennett, S. Agostinho, & B. Harper (Eds*), Handbook of Research in Learning Design Objects. Issues, Applications, and Technologies, 20-40.* Hershey & London: Information Science Reference, IGI Globa.

[2] Conole, G. (2009). The Role of Mediating Artefacts in Learning Design. In L. Lockyer, S. Bennett, S. Agostinho, & B. Harper (Eds), *Handbook of Research in Learning Design Objects. Issues, Applications, and Technologies, 188-208*. Hershey & London: Information Science Reference, IGI Global.

[3] Smyrnaiou, Z., Petropoulou, E., Margoudi, M., Kostikas, I. (2014). Patternization of an Inquiry-based design process for the construction of a structurally sound educational tool: The paradigm of a secondary development tool negotiating scientific concepts. In First International Conference on "New Developments in Science and Technology Education" (NDSTE-2014), 29-31 May, 2014 Corfu Island, Greece.

[4] Craft, A. (2001). An analysis of research and literature on Creativity in Education. http://www.creativetallis.com/uploads/2/2/8/7/2287089/creativity_in_education_report.pdf (retrieved on 10/9/2015).

[5] Loveless, A. (2003). Creativity, technology and learning –a review of recent literature. Report 4 Update: Future lab Series

[6] Loveless, A., Burton, J., Turvey, K. (2006). Developing conceptual frameworks for creativity, ICT and teacher education. *Thinking Skills and Creativity 1, 3–13.*

[7] Rabardel, P. (1995). Les hommes et la technologie, une approche cognitive des instruments contemporains, Armand Colin, Paris.

[8] Smyrnaiou, Z. & Dimitracopoulou A. (2007). Inquiry learning using a technology-based learning environment. In (Ed) C. Constantinou & Z. Zacharia, *Computer Based Learning in Sciences* (pp. 90-100). Proceedings of 8th International Conference on Computer Based Learning; 2007; Heraklion, Crete.

[9] Smyrnaiou, Z., Moustaki, F., & Kynigos, C. (2011). METAFORA Learning Approach Processes Contributing To Students' Meaning Generation In Science Learning. In D. Gouscos, & M. Meimaris (Eds.), Proceedings of the *5th European Conference on Games Based Learning* (ECGBL) (pp. 657-664); 2011; Athens, Greece: Academic Publishing Limited.

[10] Smyrnaiou, Z. and Weil-Barais. (2005). A Évaluation cognitive d'un logiciel de modélisation auprès d'élèves de collège, *Didaskalia* 27: 133-149.

[11] De Jong, T. (2005). The guided discovery principle in multimedia learning. In R. E. Mayer (Ed.), *Cambridge Handbook of Multimedia Learning* (pp. 215-229) Cambridge University Press, Cambridge.

[12] Vergnaud, G. (2008). Réponses de Gérard Vergnaud. In Merri M. (coord) *Activité humaine et conceptualisation- questions à Gérard Vergnaud*. Toulouse: PUM, p341-357.

[13] Smyrnaiou, Z. (2012). Synthesizing constructionist learning in collectives with cognitive schemes. *Proceedings from Constructionism 2012, Athens* (ed. Kynigos, C; Clayson, J. E.; Yiannoutsou, N.).

[14] Trouche, L. (2004). Managing the complexity of human/machine interactions in computerized learning environments: guiding students' command process through instrumental orchestrations. *International Journal of Computers for Mathematical Learning*, 9(3), 281–307.

[15] Béguin, P and Rabardel, P. (2000). "DESIGNING FOR INSTRUMENT-MEDIATED ACTIVITY," *Scandinavian Journal of Information Systems*, 12 (1).

[16] Engeström, Y. (1990). When is a tool? Multiple meanings of artifacts in human activity. In Y. Engeström, *Learning, working and imagining: Twelve studies in activity theory.* Helsinki: Orienta-Konsultit.

[17] Resnick, M., Berg, R., Eisenberg, M. (2000). Beyond Black Boxes: Bringing Transparency and Aesthetics Back to Scientific Investigation. *The Journal of the Learning Sciences,* 9(1), 7–30.

[18] Kori, K., Mäeots, M., Pedaste, M. (2014). Guided reflection to support quality of reflection and inquiry in Web-based learning. *Procedia - Social and Behavioral Sciences* 112, 242–251.

[19] Fisher, T, Higgins, C and Loveless, A. (2006). Teachers Learning with Digital Technologies: A Review of Research and Projects. Bristol: Futurelab www.futurelab.org.uk/litreviews (retrieved on 10/9/2015).

[20] Plowman, L and Stephen, C. (2005). Children, play, and computers in preschool education. *British Journal of Educational Technology,* 36(2), 145-157.

[21] Craft, A (2005). *Creativity in Schools: Tensions and Dilemmas.* London: Routledge.

[22] Kaufman, JC and Sternberg, RJ (eds) (2006). The International Handbook of Creativity. New York: Cambridge University Press.

[23] Conole, G and Dyke, M (2004). What are the affordances of information and communication technologies? ALT-J, *Research in Learning Technology*, 12(2), 113-124.

[24] Gee, JP (2004). *What Video Games Have to Teach Us About Learning and Literacy*. Palgrave Macmillan.

[25] Howells, J (2005). *The Management of Innovation and Technology: The Shaping of Technology and Institutions of the Market Economy*. London: Sage.

[26] Birbilis, G., Koutlis, M., Kyrimis, K., Tsironis, G., & Vasiliou, G. (2000). E-Slate: A software architectural style for end-user programming. In *Proceedings of the 22nd international conference on Software engineering* (pp. 684-687). ACM.