Integrated Interactive Constructions for Multiple Learning Activities within E-Learning Contexts

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Abstract: This paper focuses on the potential of integration of Multiple Learning Activities in Interactive Constructions (MLA-ICs), appropriate to support student learning of a specific learning subject. In fact, these constructions could be transformed using appropriate macros to support a variety of learning activities, beginning with real-life activities and gradually moving to more sophisticated scientific activities. In addition, these constructions can be transformed in a way that supports student learning of a variety of related concepts. The idea, the architecture and the interface associated with MLA-ICs was the result of a modeling process including field studies and using real students. The general concept, the design, the architecture and the interface of MLA-ICs is presented through a specific example for the learning of a mathematical theorem - Thales' theorem - within the context of tools from the well-known e-learning environment, Cabri-Geometry II (Laborde, 1990).

Keywords: Learning activities, Cabri-Geometry II, Primary and Secondary Education

Introduction

Traditional, behavioristic learning theories emphasize the teacher-telling approach, which puts the teacher at the center of the teaching (Skinner, 1968). These theories acknowledge a good, sequential presentation of the learning subject by the teacher and the passive-listening role of the learner. In the context of these traditional theories, the role of a learning activity is to give learners opportunities to implement the rules given by the teacher. These activities are usually meaningless for learners and take the form of 'drill and practice' activities. In contrast to these theories, social and constructivist theories of learning acknowledge the active, subjective and constructive character of knowledge construction, while at the same time putting the learner at the center of the learning process (von Glasersfeld, 1987; Vygotsky, 1978; Noss and Hoyles, 1996). To this end, the role of learning activities is crucial to the motivation of learners being passionately engaged in their learning (Nardi, 1996). In fact, social and constructivist learning theories acknowledge the role of real-life activities that are familiar for learners. In addition, investigative and exploratory learning activities are appreciated as playing an essential role in enabling learners to construct their knowledge actively rather than simply agreeing/disagreeing with their teachers' opinions and statements. Holistic, real-life activities are also considered to be essential in enabling learners' higher mental functions. Moreover, problem-solving activities are viewed as having a significant role to play in learners' cognitive development. Furthermore, multiple solution activities can be used to help learners to express their inter-individual and intra-individual differences in terms of the learning subject in focus and also to acquire a broad view of this subject (Kordaki & Balomenou, 2006).

Constructivist computer learning environments are ideal for implementing all the types of activity described above (Laborde and Laborde, 1995). Dynamic Geometry Systems, such as the well-known educational software Cabri-Geometry II (Laborde, 1990), provide learners with a variety of capabilities (Laborde, 1990; Mariotti, 1995; Holzl, 2001), namely: a) high level of interaction, b) direct manipulation of the geometrical constructions formed by using the 'drag mode' operation and the tools provided. Learners can exploit this capability to form and verify conjectures and hypotheses by directly manipulating the geometrical figures they constructed and reflecting on the variety of figures constructed, while at the same time conserving their properties, c) visual feedback on learner actions. This feedback can help students to self-correct their learning attempts, d) numerical feedback on a variety of mathematical entities and mathematical relationships. This kind of feedback can encourage learners while forming and verifying mathematical conjectures and generalizations, e) a variety of tools for the digital representation of a number of concepts of Euclidean geometry, f) a variety of tools of different cognitive transparency, from which learners can select the most appropriate to express their knowledge and to solve problems in multiple and different ways, g) multiple and linked representation systems. Using a variety of representation systems, learners can observe how the variation of a variable in one system can affect the variation of this variable in another representation system, h) extension through the availability of specific macro construction. In fact, Cabri can be extended by its users - teachers, researchers and learners - who are able to add specific macros to its interface.

Designers of e-learning activities have to exploit the advantages of the electronic media that they have decided to use to the full, while at the same time taking into account modern theories of learning. Cabri has strong capabilities for the design of learning activities that encourage learners to: take an investigative perspective, express their inter-individual and intra-individual learning differences, make self-corrections, formulate and verify conjectures and exploit the advantages to be had from negotiating their knowledge with that of their classmates in cooperative settings (Straesser, 2001). In addition, authentic meaningful real-life learning activities can be integrated within the context of Cabri to develop strong learner motivation. Six types of interactive constructions, supporting the realization of equal-in-number learning activities, have been proposed as appropriate to be performed by students within the context of Cabri-Geometry II (Laborde, 2001; Kordaki & Balomenou, 2006; Kordaki & Mastrogiannis, 2006), namely: a) *Cognitive transparent interactive constructions.* These constructions can help learners to form/verify conjectures and hypotheses by engaging the learner to focus on the alteration of the form of a geometrical construction using the drag-mode operation. For example, when a student draws a triangle and the bisectors of its angles, they can conjecture that 'the bisectors of the angles of a triangle always intersect internally at a single point'. In this way, students can also verify this conjecture, somehow formed from their general experience. b) *Cognitive transparent interactive constructions with an emphasis on the display of specific measures.* These constructions can help learners to form/verify conjectures by focusing on the numerical data automatically collected during the alteration of a geometrical construction using the drag-mode operation. c) *Cognitive opaque interactive constructions interlinked with interactive formulae.* By interacting with this kind of construction, learners can be helped to verify a formula by focusing on the numerical data automatically collected during the alteration of a geometrical construction using the drag-mode operation. d) *Cognitive opaque interactive constructions.* These constructions can support students to participate in activities where they have to explore such geometrical constructions with some of their properties hidden and which they then have to discover. e) *Interactive constructions simulating real-life problems*. In the context of Cabri, real-life problems can be simulated by constructing specific macros (Kordaki, 2005). Such real-life problems can help students to develop strong motivation in their learning (von Glasersfeld 1987). f) *Multiple, interactive individual constructions* supporting the performance of multiple-solution activities. As Cabri provides a variety of tools and operations, these can be effectively combined to support the performance of multiple-solution activities. Specific constructions allowing the integration of all the above type of activities have not yet been reported.

In the next part of this paper, the design and the architecture of these types of interactive constructions –the MLA-ICs- are presented, followed by a typical example of this architecture, constructed for the learning of Thales' theorem within the context of Cabri-tools. The proposed architecture is subsequently discussed and conclusions are drawn.

The Design of Multiple-Learning-Activity Interactive Constructions

The design of MLA-ICs was based on a process of modeling (Kordaki, 2004) consisting of the design of three sub-models, namely: i) the subject-matter model emphasizing the essential parts of the learning subject and the student activities necessary for its learning, as have emerged from the literature, ii) the learning model, taking into account modern, social and constructivist theories of learning (von Glasersfeld, 1987; Noss & Hoyles, 1996; Vygotsky, 1978), and iii) the students' model for performing essential activities aiming at the learning of the specific learning subject in focus. These models were constructed at two levels: a) the educational level, where the models were described in educational terms and b) the design level, where these models were interpreted in terms of design specifications, taking into account the features of the educational software proposed for use. Taking these specifications into account, appropriate educational paper and pencil and electronic materials were formed. To establish the reliability of both these materials and the implied aforementioned models, a three-phase design was implemented (Kordaki, 2004): a) a *top-down design* phase, where the designers' knowledge of the three aforementioned models was taken into account to form educational materials regarding the learning concepts in focus, b) a *testing phase* for the designed learning materials, using real students with emphasis on the feedback the students gave, and c) a *re-design* phase where the data emerging from the testing phase were exploited for the re-design of the three aforementioned models and the reformation of the learning materials, including the software-based constructions dedicated for student interaction. Based on the data, these last models can be viewed as being more consistent with student learning characteristics, in terms of the learning concepts in focus. With these last models being taken into account, MLA-ICs were formed. The aforementioned design process and the architecture of MLA-ICs are presented in some detail in the next section of this paper within the context of a specific example: the formation of learning materials for Thales' theorem exploiting the features of Cabri-Geometry II.

The top-down design phase

In designing the *subject-matter* model, the designer considered it essential to provide learners with opportunities: a) to verify the Thales' theorem formula by their own involvement in experimental situations, b) to recognize geometrical problems where the Thales' theorem will be useful and to apply the associated formulae successfully to provide solutions to these problems, and c) to acknowledge the significance of Thales' theorem in solving real-life problems. On the basis of the above, four learning tasks were designed:

Task1. Using the appropriate Cabri-tools, construct 3 parallel lines e1, e2 and e3 and two other lines e4 and e5 that intersect lines e1, e2, e3 on points A, B, G and A?, B??a? G?correspondingly. Define the segments ? ?, ? G, ? ???and ??G?. b) Calculate the fractions ? ?/? ???and ? G/? ?G?. Could you form any conjecture; c) Drag e1, e2, e3 and e4, e5 and automatically tabulate the numerical data. Focus on this data. What do you observe? Could you form any generalization? The aim of this task was to encourage students to verify the Thales' theorem formula by their own active experimentation with appropriate interactive geometrical constructions.

Task2: Using the appropriate Cabri-tools, construct a trapezium ABCD and a parallel line to its bases that intersects segments AD and BC on points K, L. Could you use the Thales' theorem you learned in the previous task? The aim of this task was to assess student knowledge acquired in the previous task and to give them the opportunity to recognize geometrical problems where the Thales' theorem can come in useful.

Task3: Using the appropriate Cabri-tools, construct a triangle ABC and a parallel line (e1) to its base BC from vertex A. Construct also a parallel line e2 to the base BC that intersects segments AB and AC on points ZK. How can you use the Thales theorem you learned in Task 1? The aim of this task was also to assess student knowledge acquired in the previous tasks and to give them the opportunity to recognize various geometrical problems where the Thales' theorem can come in useful.

Task4: In the dam presented on this screen (Figure 1), the lengths of segments AB, BG and A'B' are known. Can you find the length of segment B'G'? The interactive construction in Figure 1 was given ready for students to interact.

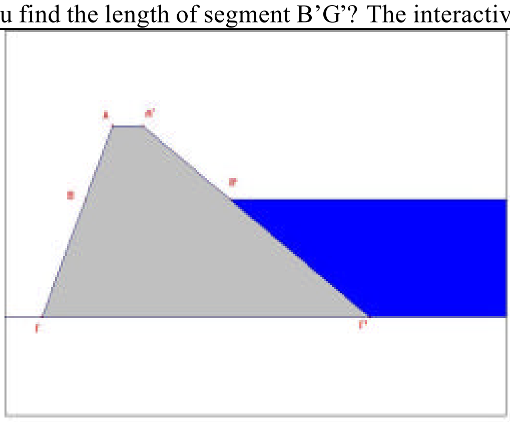

Figure 1. Diagrammatic presentation of the dam profile

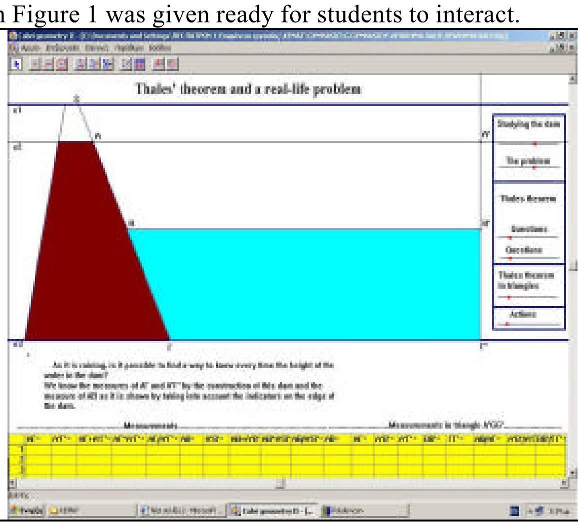

Figure 2. The general interface of MLA-ICs for the learning of Thales' theorem through a real-life activity

The aforementioned tasks were presented to the students on paper activity sheets. The architecture of these activity sheets was in five parts: a) the aim of the activity, b) an analytical description of the keystrokes necessary for the design of the geometrical construction for interaction and study, c) instructions on how to use the necessary Cabri-tools, d) a set of open investigative questions and e) a set of questions focused on specific topics. The aim of these questions was to help students to progress should they become stuck.

The *learning-model* was constructed so as to exploit Cabri capabilities in shaping a learning context to encourage students to: a) be actively involved in the construction of their knowledge by exploiting the variety of features provided, b) make investigations and form/verify conjectures, hypotheses and generalizations by attempting direct manipulation of each geometrical construction at hand, c) reflect on both visual and numerical feedback from their actions, leading to self-correction, d) be motivated by being involved in holistic, real-life tasks by providing appropriately designed simulations of real problems. Construction of the *student- model* for the learning of the previously mentioned subject-matter and performing the said tasks within the context of the aforementioned learning-model proved impossible at this stage of the experiment, as no relative information was available in the literature. Since no extra information from the design of this model was forthcoming, the previous models and, subsequently, the aforementioned tasks, were not transformed at this stage.

The testing phase

All the interactive constructions and the activities designed in the previous phase were tested in a genuine classroom during a teaching experiment (Cobb and Steffe, 1983) with the participation of 25 ninth grade students. The duration of the experiment was about 2 hours and the data sources were the students' working sheets and the field notes of the researcher. In terms of research methodology, this is a qualitative study (Cohen and Manion, 1989). The analysis of the data emerging from this experiment showed that: a) all students verify the truth of the Thales' theorem formu la after experimentation with the interactive construction they formed following the instructions given. Specifically, students dragged the parallel lines e1, e2, e3 and the lines e4 and e5 and automatically tabulated the numerical data for the fractions ??/? ?? ?and ? G/??G. However, students were unable to generalize or form Thales' statement. b) no student was able to use Thales' theorem in the remaining tasks. In my opinion, this was due to the fact that they did not invent this theorem but simply verified it. c) all students expressed their interest in studying the real-life problem - the dam problem - because they found meaning for Thales' theorem in this problem. However, students had difficulties in understanding the similarities of the geometrical constructions implied in all the tasks given, and consequently in finding it reasonable to use Thales' theorem. Actually, students conceived all the tasks as being different. d) all the students became bored due to the, for them, excessive number of keystrokes needed to form the constructions mentioned in the tasks. In fact, the key stroking process was, indeed, time-consuming and detached the students' focus from the learning aims of each specific construction. e) students were confused shifting from paper and pencil, where they read about the tasks and answered the relative questions, to Cabri where they performed the tasks. As a result, it was decided to transform the paper and pencil materials into Word documents and to repeat the whole experiment. Unfortunately, the results were the same; consequently, major changes in the design of the activities were deemed necessary, taking into account all the above feedback. These changes are presented in the next section of this paper.

The re-design phase and the generation of the idea of MLA-ICs

Major changes in the design of the whole activity-context were decided upon due to the feedback given by the students during the 'testing phase' of this experiment. These changes related to: a) providing the students with ready interactive constructions to experiment with, aiming to avoid cognitive load and superfluous keystrokes, b) avoiding the use of mixed materials, such as paper and pencil, Word documents and Cabri constructions, and integrating all the necessary information into the same Cabri screen, including questions, task description, technical instructions and interactive geometrical constructions, c) avoiding the association of one specific interactive construction per task and integrating all the aforementioned interactive constructions into one interactive construction. This integrated construction could be used to realise all 4 learning tasks. To accomplish this, it was essential to use the features of Cabri to form specific macros. To implement all these decisions, we came up with the general idea of MLA-ICs. To embody this idea, a general *architecture* of MLA-ICs was created and displayed on a specially-designed interface (see Figure 2). The aim of MLA-ICs is to help students study specific learning concepts through a variety of tasks. This architecture is in five parts, namely: a) information, b) open questions, c) focused questions, d) help and e) a number of Jointed interactive Constructions (JCI, I=1...n), supporting student experimentation with different aspects of the learning concept, different activities and different learning contexts such as real-life contexts, geometrical contexts etc. MLA-ICs for the learning of Thales' theorem consisted of the following Jointed Constructions (JC):

JC1: This is an interactive simulation of the real-life problem, viewed as appropriate for giving meaning to the learning concepts in focus. Figure 2 presents the interactive construction, allowing student experimentation with Thales' theorem in the aforementioned real-life problem (Task 4). It is essential to encourage students to start with this construction simulating a real-life problem - the dam problem - and then proceed to adapting this construction in such a way as to facilitate the student experimentations and investigations necessary to complete the remaining 3 tasks. The real-life problem was deemed appropriate for motivating students to study Thales' theorem. This problem could be posed in the following way: 'The measures of segments AG and A'G' are known from the construction of the dam. The measure of segment AB can be also calculated because there are some specific indicators on the edge AB. However, we need to know the height of the water at any time so that we can calculate the amount of the water in the dam. This is important for the distribution of this water to the people of the neighboring village according to their rights. Is there any way to find this height without swimming or using any electronic tachometric devices?'

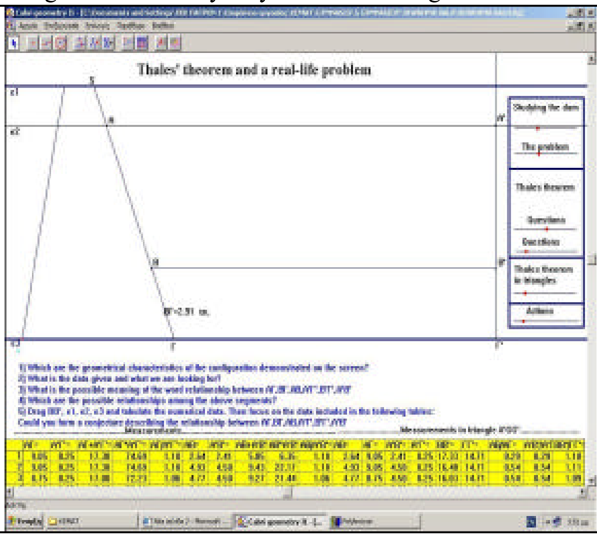

Figure 3. The general interface of MLA-ICs for the learning of Thales' theorem in a geometrical sense

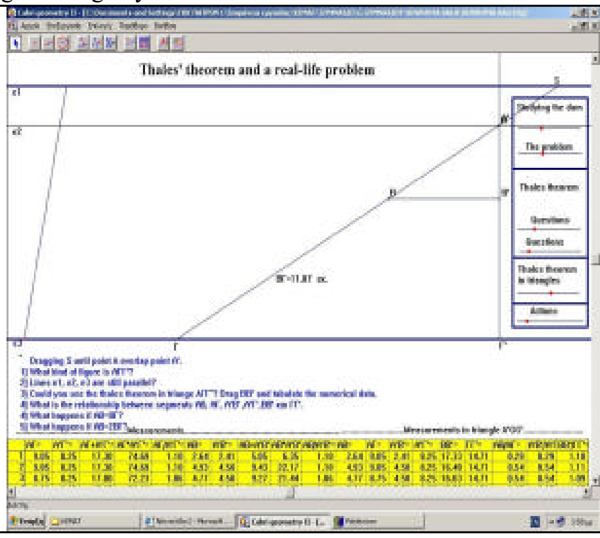

Figure 4. The general interface of MLA-ICs for the learning of Thales' theorem in triangles

JC2: This is a basic interactive construction (see Figure 3) that is appropriate for students to study Thales' theorem in a geometrical sense (Task 1). This can be produced by automatically omitting the water and the cement from construction JC1 using specific macros.

JC3: This is an extra interactive construction necessary for the students to study a specific case such as the use of Thales' theorem in triangles (task 3, see Figure 4). This can be produced by dragging line e4 (illustrated in construction JC2) until point A overlaps point A'.

JC4. This is another interactive construction necessary for students to study the use of Thales' theorem in trapeziums (Task 2). This can be produced by illuminating only part AA'GG' of JC2 and hiding the rest of the construction by using specific macros.

The general interface of MLA-ICs. As is shown in Figures 2, 3 and 4, the interactive construction at hand is in the centre of the screen and can be managed through both direct manipulation and a navigation bar. Each of the parts of this bar is dedicated to the management of a specific part of the said construction. Each part of this interactive construction supports the performance of a specific learning activity. Each part of the navigation bar consists of specifically designed buttons (top right sector of the screen). By using some of these buttons, a part of the whole construction could be illuminated or hidden. Other buttons could also be used to provide: a) text-based information regarding the sub-activity at hand. b) appropriate questions so as to assess student knowledge, and c) instructions to manage the construction in focus.

Conclusion

This paper has presented the idea of integrated-interactive constructions that could support the realization of multiple learning activities (MLA-ICs). This idea and the specific design of MLA-ICs have emerged from a field study using real students. MLA-ICs were designed as a result of the modeling process, including the construction of three models: a) the subject-matter model, b) the learning model and c) the learners' model while performing the specific tasks proposed for learning the subject matter within the framework of the learning model. This modeling process was realized through three phases: a) a top-down design phase, where the designers' views on the aforementioned models was taken into account, b) a testing phase, where the learning materials based on this previous design were tested using real students and c) a re-design phase, where the feedback given by the students was taken into account when redesigning the whole learning context. As a resul, the idea of MLA-ICs was generated. A specific architecture for the design of MLA-ICs also emerged as well as an interface-design appropriate for the interaction of students with these constructions. The proposed architecture for MLA-ICs is in five parts: a) information, b) open questions, c) focused questions, d) help and e) a number of jointed interactive constructions supporting student experimentation with different aspects of the learning concept, different activities and different learning contexts such as real-life contexts, geometrical contexts etc. Each part of the proposed architecture is projected on specific parts of the computer screen. Consequently, the interface-design for MLA -ICs is also in five parts. Specific parts of the MLA -ICs can be illuminated/hidden using specific buttons. For MLA -ICs to be constructed, it is necessary to have the ability to construct specific macros. To clarify the concept of MLA -ICs, an example of such constructions has been demonstrated. These constructions were dedicated for the learning of the mathematical notion of Thales' theorem, exploiting the features of Cabri-Geometry II.

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