LEARNING WITHIN DYNAMIC GEOMETRY SYSTEMS: STUDENTS' VOICES

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Abstract:
This paper presents the results from both; a quantitative and qualitative study investigating students' opinions about the use of tools of the well known educational software Cabri-Geometry II [1] in their every day classrooms. Specifically, 340 students participated in learning experiments –in several regions of Greece- where the tools of the aforementioned software were used in combination with appropriate lesson plans. Teachers used these tools to construct specific interactive constructions and lesson plans in the context of a wider European teachers' online community in the frame of the Socrates Comenius 2.1 Project *VccSSe – Virtual Community Collaborating Space for Science Education*. After the aforementioned experiments, students were asked to complete a questionnaire including both; closed and open questions. The results emerging from this study indicated that the majority of pupils liked the use of these tools in their every day classroom practices and addressed various reasons to support their opinions. Students also proposed the use of technology not only for the learning of Geometry but also for other subjects included in school curricula.

Keywords: Cabri Geometry II; students' voices; secondary education; Geometry

1. Introduction

The significant role of computer tools and environments in effectively mediating the students' learning actions and especially those related for the learning of mathematical concepts have been acknowledged by many researches [2-3]. Dynamic Geometry Systems (DGS) are among the essential computer environments that efficiently support mathematical learning related to various concepts of Euclidian Geometry [4-5]. Within the context of DGS, Cabri Geometry II takes a central position. In fact, Cabri-Geometry II is a widely-known educational software that has been designed to support constructivist mathematical learning settings [3]. In particular, Cabri provides students with potential opportunities in terms of: a) means of construction, providing a rich set of tools to perform

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a variety of geometrical constructions referring to a variety of concepts concerning Euclidean Geometry. These tools can be exploited by the students in order to perform a number of different geometrical constructions and to deal with a variety of geometrical problems. In this way students can develop alternative approaches to the problems given at the same time expressing their inter- and intra-individual learning differences and also while developing a broad view of the concepts in focus [6]. b) Tools to construct a variety of representations, both numerical and visual, such as geometrical figures, tables, equations, graphs and calculations. These representations are of different cognitive transparency; consequently, students can select the most appropriate tools to express their knowledge. In this way, students have the possibility of expressing both inter-individual and intra-individual differences. The representation systems used also affect the kind of knowledge that students construct [7-8], c) Linking representations, by exploiting the interconnection of the different representation modes provided. In this way students can observe how the variation of a variable in one system can affect its expression in other representation systems [9]. As a result, students can form dynamic and integrated views of the concepts in question, d) Dynamic, direct manipulation of geometrical constructions by using the 'drag mode' operation. This essential operation gives learners the possibility of directly experimenting with geometrical constructions. In these Cabri-constructions, their geometrical properties are retained under dragging, while their visual output differs. The 'drag mode' can be used in three modes: an 'exploratory' mode, a 'verification' mode and an 'adjustment' mode [10]. Thus, students have the opportunity to form and verify hypotheses and conjectures by handling, in a physical sense, the theoretical objects which appear as diagrams on the computer screen [4]. By using 'drag mode', students can also form dynamic views of the concepts in focus [8]. e) The possibility of collecting large amounts of numerical data. Cabri provides the opportunity for automatic tabulation of large amounts of specific numerical data viewed as appropriate for the study of the geometrical concept in focus. In particular, the 'drag mode' can be used in combination with automatic measurements of specific elements of the geometrical constructions under study. These measurements can be automatically tabulated, providing learners with opportunities to reflect on them and form and verify conjectures about specific geometrical concepts and relationships. f) Interactivity and feedback; intrinsic visual feedback and extrinsic numerical feedback, providing learners with opportunities to form and verify conjectures as well as to self-correct their constructions. This is important, as learner actions are closely connected with their consequences, contrary to the static and silent paper and pencil environment where there is no possibility of providing immediate response to those actions [11], g) Presenting information to the students in text form, for example, the presentation of the tasks at hand, h) Capturing the history of student actions to provide teachers and researchers with a valuable amount of data for further studies, and i) Extension. Certain operations could be added as buttons on the Cabri interface following the formation of specific macros.

Cabri also presents 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 from the negotiation of their knowledge with the knowledge of their classmates in cooperative settings [10, 5]. In addition, authentic meaningful real life learning activities can be integrated within the context of Cabri, activities that can develop strong learner motivation.

Based on the above, it was decided to design an online learning course for teachers aiming towards their familiarization with the features of DGS and especially of Cabri and also the design of interactive learning constructions and appropriate lesson plans as well as their implementation in real classroom practices. However, research suggests that, for the majority of teachers, solely providing technology is insufficient for the successful integration of technology into their teaching [12]. It has been suggested that adequate training and collegial support boost teachers' willingness to integrate technology into their teaching and to develop successful technology-assisted teaching practices. To this end, the design and implementation of a virtual space within MOODLE [13] for the use of Cabri by mathematics teachers was decided. MOODLE is an open source Learning Management that works on school intranets and can be accessed at any time by anyone who has access on the Internet. This space is integrated into a wider virtual space called 'Virtual Community Collaborating Space for Science Education (VccSSe; [14]) and named VccSSe-math space. VccSSe is dedicated for Sciences teacher education across Europe, aiming at the adaptation, development, testing, implementation and dissemination of training modules, teaching methodologies and pedagogical strategies based on the use of Virtual tools and Instruments, with the view of implementing them in the classroom, through the use of Information and Communication Technology tools. In the context of VccSSe-math space 13 teachers were trained about the pedagogical and technical features of Cabri. Then, they constructed interactive constructions and also supported them by appropriate lesson plans. Next, they realized these lesson plans using Cabri in their classrooms. After that, students were asked to express some opinions about the use of Cabri in their daily lessons of Geometry.

In the following part of this paper the structure of the VccSSe-math space is briefly presented. Next the context of the study investigating specific students' opinions regarding the use of Cabri is described. Then, the results of this study are reported and finally, discussion and conclusions are drawn.

2. The structure of VccSSe-math space

VccSSe-math space is dedicated for Mathematics teacher education across Europe for the appropriate use of Cabri Geometry II. The design of this space is based on social and constructivist theories of learning [2, 3]. The well-known educational software Cabri-

Geometry II was selected to help teachers introduce Dynamic Geometry Systems into their teaching practices. The context of VccSSe-math space, is consisted of three parts: a) the theoretical part including background issues regarding the learning possibilities in the context of DGS and especially within Cabri. This part is in text and in multimedia format [15, 16]. b) the familiarization part including familiarization activities where representative activities are presented click by click in order to support teachers' familiarization with the tools provided by Cabri [15, 1]. This part is also in text and in multimedia format and c) the activity part where different types of activities are presented for online exploration using Cabri-Jawa files [17]. These activities are integrated with appropriate questions for the students as well as instructions about the technical manipulation of them. By experimenting with these activities, teachers have the chance to realize their diverse types and also use them with their students. Specifically, six types of learning activities [10, 18, 19, 20] have been designed to be performed by the teachers using the tools of Cabri-Geometry II during their participation in the context of VccSSe-math space, namely: a) *Forming/verifying conjectures* by focusing on the alteration of a *geometrical construction* using the drag-mode operation. b) *Forming/verifying conjectures* by focusing on the *numerical data* automatically collected during the alteration of a geometrical construction using the drag-mode operation. c) *Verifying a formula* by focusing on the *numerical data* automatically collected during the alteration of a geometrical construction using the drag-mode operation. d) *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. In the context of these activities, it is possible to integrate all the possibilities provided by Cabri into any of the possible different types of activities. e) *Black-box activities*. Students can participate in activities where they have to explore geometrical constructions with some of their properties hidden, which they then have to discover. f) *Constructions simulating real life problems*. Such real life problems can help students to develop strong motivation in their learning and approach mathematics as a human activity [21; 22] as well as put mathematical concepts into an interdisciplinary context [23].

2. The context of the study

In the context of VccSSe, 13 Greek teachers were trained for the use of the training materials and the interactive constructions provided by the VccSSe-math space. Then, they created their own interactive constructions (called 'Virtual Tools and Experiments'; VT&Es) and also specific lesson plans to support the use of these constructions. Finally, these teachers used these constructions and lesson plans -in lessons- with their students in their classrooms. In these lessons, 340 pupils participated in total. All teachers constructed these interactive constructions using the tools provided by the well known educational software Cabri-Geometry II. At the end of each lesson students were asked to answer–in a paper sheet- the following questions: 1) What did you like most in the lesson where Virtual tools and experiments were used? 2) What did you dislike in the lesson where Virtual tools and experiments were used? 3) How helpful were the VT&E's in the understanding of the concepts in question? 4) Do you want the use of Virtual tools and experiments by your teacher again? 5) Write other comments.

Students were free to give any response to the first, second and fifth question. Thus, these responses were qualitatively analyzed and categories of responses were formed [24]. Students' responses to the third and forth questions were collected using a 5-level Likert scale and are presented quantitatively. In the following section, the results of the data collected from the students' responses to the questionnaire given are presented.

3. Results

What students liked about Virtual tools and experiments. A considerable number of students expressed their preference for the use of computers in their classrooms as suitable to their culture and era in contrary to the use of paper and pencil. In their own words "*The lesson became easier than in the paper and blackboard environment; when using computers, low grade students understood the lesson'*. Some students also expressed their preference for group working while using VT&E. Regarding the use of Cabri-Geometry II, students expressed their interest in diverse ways including: a) drawing, b) experimenting, c) understanding, d) feelings, and e) scaffolding.

Drawing within Cabri: Students said that they were attracted by the possibility of drawing colorful shapes using its tools. In fact, this possibility helped them become interested and focused during the specific lesson. Some students also expressed that the construction of shapes using the tools of Cabri-Geometry II was more precise, correct, clear and easier than the constructions in the blackboard. These students suggested that drawing within Cabri doesn't leave many opportunities for mistakes. Students also found it easy to measure some geometrical entities within the context of Cabri.

Experimenting within Cabri: Students were impressed by the possibility of dynamic experimentation with geometrical shapes within Cabri by using the 'drag mode' operation. Students realized that, using this operation, they have the ability for easy and fast creation of multi-forms of geometrical shapes, while at the same time conserving their properties. They came to understand the dynamic transformation of shapes as motion of shapes. In fact, students came to see dragging as a dynamic (fast and easy) transformation of geometrical shapes and the correspondent measurements by using the 'drag mode' operation: 'we can observe and study many forms of the same geometrical construction simultaneously'. Some other students realized that by using this operation 'we had the ability to study the shapes'.

Understanding of Geometrical concepts within Cabri: Students also expressed that they could acquire better, easier and faster understanding of geometrical concepts when dynamically experimenting with geometrical shapes using Cabri than when using the blackboard, by exploiting the capability to quickly and easily study diverse forms of the same geometrical shape using the 'drag mode' operation. Students also expressed that they understood better and easier the concepts in question within Cabri than in paper and blackboard, due to representational and dynamic transformation capabilities of this software. Most importantly: students expressed that '*Some difficult topics for the typical paper and blackboard environment became easier and understandable by the use of technology'*. Other students also commented that 'we became active and quickly understood the topics in question'.

Feelings about the use of Cabri: Here as well, some students expressed that when they participated in lessons where Cabri was used, they felt pleasant, entertained, interested and focused. Some other students expressed that, compared to paper and pencil, they found Cabri: creative, 'nice' and interesting.

Scaffolding within Cabri: Students expressed that everything was helpful when they used VT&E. Specifically; they realized that the use of visual images was very helpful for them to easily understand the concepts in question. In addition, they expressed that the tools provided by Cabri helped them to easily use mathematical rules, to automatically perform some specific geometrical constructions and measurements as well as automatic tabulation of numerical data. Finally, some students emphasized the diversity of tools provided as helpful to construct and elaborate with a plethora of geometrical shapes.

General remarks: Students characterized the way of teaching by using of Cabri in their school practices as: 'It is audacious and modern to school practices', 'it is good, visual, interesting and especial', 'this method of teaching is fast, interesting, direct, effective, easy to use and easy to understand'

2. What students disliked about Virtual tools and experiments. A minority of the students experienced some difficulty using and learning to use the software. Regarding the former, students noted that drawing was time consuming. Regarding the latter, students noted that there was no help from the teacher during the use of the software and it's complexity and difference from traditional mean made it hard to learn how to use. A few students also remarked that the conditions under which the experiments where carried out were less than satisfactory, namely, there were too many students for the computers available, it was dark and noisy in the room and generally, the experiments were not very well organized in terms of facilities.

3. How helpful were the VT&E's in the understanding of the concepts in question? The majority of students found the use of VT&E's helpful in the understanding of the concepts in question (Very helpful: 72%, Somewhat helpful: 25%, Not all: 3%)

4. Do you want the use of VT&E by you teacher again? The majority of students expressed their desire to participate again in lessons where VT&E could be used by their teachers. In terms of students answers: Most of them liked the regularly use of VT&E (Yes, regularly: 79%) while some of them answered that they prefer the use of VT&E in combination with traditional p-p teaching approaches (Yes temporarily: 18%). Only few students expressed their dislike to use VT&E in their learning practices (No: 3%).

5. Other comments. Many of the students remarked that they would like to participate in more lessons where virtual tools and experiments will be used, in their daily school lives. If possible, they would like this method to be used in all subjects, especially scientific ones like Physics and Chemistry for better understanding.

3. Conclusions

This paper presented a study investigating the opinions of secondary students' opinions regarding with the use of tools of the well known educational software Cabri-Geometry II in their daily classroom practices. Specifically, 350 students participated in lessons where the tools of the aforementioned software were used for the learning of basic concepts of Euclidian Geometry. By using these tools, specific Virtual Tools and Experiments (VT&Es) were formed and provided to these students to interact. A first glance of the results -emerged from this study- shows that the majority of students expressed strong interest in the use of VT&Es in their daily classroom practices not only for the learning of Geometry but also for the learning of the rest of the subjects included in school curricula. Students used various arguments to support their opinions about the features of these VT&Es they liked most, such as: a) potential possibilities for drawing, b) dynamic experimentation, c) scaffolding features, d), better understanding and e) positive feelings such as feelings of pleasure, curiosity, convenience, gratification and support.

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