STUDENTS' ATTITUDES ABOUT INTEGRATING DYNAMIC GEOMETRY SOFTWARE IN TEACHING CONSTRUCTIONS IN GEOMETRY

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Abstract

The purpose of the research was to learn about students' attitudes toward and evaluation of the pedagogical procedure based on integrating dynamic geometry software (DGS) in dealing with construction problems in geometry. The research population consisted of mathematical education students. It was observed that the students preferred to use DGS when dealing with construction problems and appreciated the dynamic features of DGS to a large extent, and that the developed pedagogical procedure improved the students' mode of usage of the computerized environment. We suggest that the explored teaching procedure enables students to construct and assimilate more complete and wide-scale knowledge.

Integrating Technology in the Classroom – Benefits and Problems

Over the few last decades technology has become an important component of mathematical education. Numerous recent studies have indicated that integration of technology into math classrooms has a significant impact on teaching mathematics by enhancing the acquisition of mathematical learning (Monaghan, 2001; Hollerbands, 2007). Unfortunately, despite these benefits, in practice such integration meets serious difficulties on the part of teachers as well as students (Cuban, Kirkpatrick, & Peck, 2001).

As has been reported previously, the way to effectively integrate technology into the mathematical classroom depends on the teacher, on his experience using the technology, and on his proper selection of mathematical tasks that allow him to take advantage of the technology's features (Mously, Lambdin, & Koc, 2003; Lawless & Pellegrino, 2007). It is generally known that teachers usually resist technological innovations, protesting that they impede teaching by taking time and distracting students from the subject (Abboud-Blanchard & Lagrange 2006; Jung & Latchem, 2011). Therefore, using computers and learning how to work with particular software becomes a real challenge for teachers. Many teachers don't feel comfortable with new technology. Even after they have gotten acquainted with the chosen technology, they may still be a long way from being able to effectively integrate it into their teaching.

Referring to students' attitudes towards technology integration in math teaching, several studies (Nuggent, Soh, & Samal, 2006) have suggested that technology could motivate students to learn mathematics. At the same time, numerous studies have indicated that not all students are confident in the use of technology, nor are they all convinced of the benefits of computer-aided teaching (Trouche, 2005). D'Souza and Wood (2004) found that students frequently mistrusted software and felt more comfortable with traditional methods; namely, they preferred using pen and paper, because this was more reliable and easier.

Another aspect of the integration of technology into mathematical teaching is the fact that such integration affects both the pedagogical procedure and the content of the course (NCNM, 2000; Oner, 2009; Ruthven & Hennessy, 2002; Lawless & Pellegrino, 2007). Unkefer, Shinde, & McMaster (2009) believe that the implementation of technology in the educational process induces teachers to look for an appropriate learning environment and the corresponding pedagogical procedure. According to this conception, the principle of introducing a dynamic environment into the educational process entails continual modification of the classroom and the teaching methodology. The above concept is based on the five-phase model proposed by Hooper and Reiber (1995) for adapting educational technology in the classroom, consisting of the familiarization, utilization, integration, reorientation and evolution phases.

In the current research we concentrate on the integration of Dynamic Geometry Software (DGS) into the teaching of constructions in geometry. We are convinced that the dynamic features of DGS such as the way it facilitates the construction of geometrical objects and the specification of relationships between them (Christou, Mousoulides, Pittalis, & Pitta-Pantazi, 2005), might enable users to implement the widely discussed maxim that knowing mathematics means doing mathematics. Based on recent studies and our own experience with DGS, we believe that the usage of DGS in geometry classrooms permits learners to turn studying geometry in general, and constructions in geometry in particular, into a process of experimentation, exploration, as well as justification and verification (Oner, 2009; Barabash, Gurevich & Yanovsky, 2009). Our reason for dealing with constructions in geometry is that our research population has very limited or no experience with such problems. Therefore we suggest that the implementation of new approaches based on computer technologies can contribute to their development.

The Main Phases in the Development of the Course "Constructions in Geometry" during the Integration of Dynamic Geometry Software

The course described was given to sophomores in the teacher education program for in-service and pre-service secondary school teachers and went through significant modifications that were mainly based on the results obtained from our research during the last approximately 10 years.

We would like to describe very briefly how we integrated computerized tools in teaching construction problems in geometry during the research period. Here we list the critical phases of this process:

1. At first (during the period from 2003 to 2007 academic years) we taught two separate courses (by two different lecturers), namely "Computer Usage in Math Teaching" in parallel with the course "Constructions in Geometry", which allowed the students to get acquainted with DGS and practice the same basic construction problems that they had learned in the course "Plane Geometry" (which we defined as Computer-Exercising [CE] teaching procedure). Based on this practice, we developed a teaching method which provided the students with a set of guidelines for using the DGS throughout the solution of problems (Barabash et al., 2009). We found that the computer usage was quite effective. At the same time, we observed that the students had serious difficulties in dealing with the investigation of solutions.

2. Based on these results, we decided to merge those two courses into one, taught (since the 2007-2008 academic year) in a computerized classroom, in which the DGS was used in teaching mode that we defined as Computer-Integrated [CI], so that the computer became an integral part of the educational process. Our pedagogical adjustment was such that each new topic was explained and presented both analytically and by using the computer, so that the students had the opportunity to explore the topic themselves by means of the DGS. We found that the implementation of the CI procedure enabled students to improve their achievement significantly even for relatively difficult problems. Here it is necessary to emphasize, that using DGS tools in teaching led us towards revisions of routine pedagogical procedures (Gurevich & Gorev, submitted to publication).

3. The further development of the course through continual modification of the classroom according to our experience of integrating technology (from 2009 academic yeas onwards). We refer to this phase as the "Computer-Integrated Experienced" (CIE) mode of teaching. Here we mean more adequate interpretation of the information obtained by means of the DGS accompanied by discussions with a focus on various aspects of the DGS' contribution.

The subject of the current study is the attitudes of students towards integrating DGS into the teaching constructions in geometry, as indicated by their evaluation of the pedagogical procedure for the course resulting from this integration. Moreover, we were interested in learning about the impact of an integrative method of using technology on students’ mode of usage of the computerized environment.

Research Population

The research population consists of 46 students individuals from three groups of second-year students in the educational program for secondary-school math teachers of the Math Teaching Department at Achva Academic College of Education. The groups were drawn from three different academic years and were taught using three different procedures: Group 1 (18 students) from 2003 (CE teaching procedure), Group 2 (13 students) from 2008 (CI teaching procedure) and Group 3 (15 students) from 2011 (CIE teaching procedure). Here it is important to emphasize that the students in all the groups had the similar background, namely more or less same math abilities (the students had practically no previous experience with construction problems) as well as same level of computer proficiency

The research consists of both quantitative and qualitative analyses. At the end of each academic year, the students were asked to answer a questionnaire (see Appendix). The questionnaire was built based on our previous finding (Barabash et al., 2009) as well as on the results presented in the literature (Pea, 1985; Laborde, 2001), which indicated to three main modes of usage by DGS, namely as a visualization tool to understand the problem (Visualization), as a tool in the search for a construction strategy (Problem solution) and as a tool to analyze the conditions for existence and uniqueness of the solution (Solution investigation). The questions were formulated to determine whether students felt that the dynamic geometry software assisted in the instructional process, and if so in which manner (within the three specified modes). In addition, in an open question, the students from Group 3 were asked to describe their attitude with respect to the above closed questions.

Besides this questionnaire we used two more tools for triangulation of the data in order to gather different data aiming to obtain a deeper picture (Shkedi, 2011): teaching evaluations by students administered by the college authorities routinely and a researchers' journal. All of these tools were used to gather data in each of the three periods analyzed. The data about the students' attitudes were obtained from both the questionnaire and the teaching evaluations.

In the quantitative analysis, the students' attitudes were evaluated according to the percentages within each group who gave a positive answer to each question. In the qualitative analysis we performed content analysis of the data (Denzin & Lincoln, 2005), with respect to the three above-named modes of DGS usage. We grouped the relevant comments for each category (Tracy, 2010), and then performed targeted descriptive analysis (Shkedi, 2011).

Findings

First, we analyze the students' answers to the questionnaire regarding the contribution of the DGS, with respect to the three groups and corresponding teaching procedures. In Table 1 we present the percentage of students who answered that the computerized tools made a contribution to their learning out of all the students in each group.

Table 1

DGS Contribution Indicated by Students According to Teaching Procedure

Group (teaching procedure)	DGS contribution
1 (CE)	44% (8/18)
2 (CI)	69% (9/13)
3 (CIE)	93% (14/15)

The results indicate that the percentage of students who confirmed that the DGS made a contribution to their learning steadily increased from Group 1 to Group 3. Next, we analyzed the students' answers about their mode of usage of the DGS. Due to the relatively low percentage of students in Group 1 who found the DGS to be useful, we concentrated only on Group 2 and Group 3. In Table 2 we present the percentages of the students within each group that pointed to each of the three main modes of DGS usage.

Table 2

Modes of Usage of DGS Indicated by Students, According to Teaching Procedure

Mode of usage / Group	Visualization	Problem solution	Solution investigation
Group 2	46% (6/13)	38% (4/13)	69% (5/13)
Group 3	55% (4/18)	33% (4/18)	61% (4/18)

It can be observed from the results that the preferred mode of DGS usage in both groups was the solution investigation. Another relatively frequent mode of DGS usage was visualization. The results indicate that there is no significant difference between the two groups with respect to the mode of DGS usage.

In our further analysis we concentrated on the students' answers to the open question of the same questionnaire. The answers are presented according to the modes of DGS usage (namely, as a tool for visualization, problem solution and solution investigation). In Table 3 we present the repeated students' comments with respect to each mode of DGS usage.

Table 3

Students' Comments on Modes of Usage of DGS

Visualization	I believe that working with DGS is very important for us; by using DGS we get the exact figure which perfectly illustrates a given problem.
Problem solution	DGS serves helps at the stage of solution, since one can try various methods of solution without much effort in comparison to using pen and paper. DGS does not help; finding a solution does not relate to working with DGS.
Solution investigation	Dragging enables me to test the conditions under which the solution holds true as well as to find all existing solutions. The main advantage consists of the possibility to understand what happens when dragging a figure.

As can be seen from the students' answers, they consider DGS to be a useful tool which enables them to see the problem and to understand it better, and they find that DGS permits them to try various solutions and to verify them in an easy way. We can see that the students find DGS to be especially useful for solution investigation. At the same time, the students' comments demonstrate their awareness about the existing restrictions when working with this math software. The students admit that the computer does not provide them with concrete ideas about what the solution can be.

Another aspect of DGS usage that we were interested in testing was whether the students preferred to first see formal explanations on the blackboard and then to practice the material with the DGS, or vice versa. The students' answers to this question are presented in Table 4.

Table 4

Students' Preferences for Order of DGS Usage and Formal Explanations

Group \ Sequence of usage	First DGS and then formal explanations	First formal explanations and then DGS	Both methods combined	DGS is useless
Group 2	7% (1/13)	46% (6/13)	15% (2/13)	30% (4/13)
Group 3	28% (5/18)	39% (7/18)	28% (5/18)	5% (1/18)

The results indicate that a significantly lower percentage of students considered DGS to be useless in Group 3 than in Group 2. In addition, it can be seen that in both groups the largest percentage of students preferred the "conventional" order, where the teacher first explains the material on the blackboard and the students then explore this material by using DGS. At the same time, the results indicate that more than 50% of students in Group 3 approve the other sequences, where practice by using DGS comes before formal explanations or that order may vary with respect to subject or problem.

We also analyzed the students' comments and suggestions about the "place" of DGS within the lesson. We present here the repeated quotations from the students' answers, according to the suggested order of DGS usage:

> **First DGS and then formal explanations**
> I prefer first to try to solve the problem by using DGS, and then to formulate the solution. In this way I try to find the solution by myself. Besides that, in case I don't succeed, it is still more interesting to me when we discuss this problem in class.
>
> **First formal explanations and then DGS**
> I prefer that the teacher explains the material on the blackboard and after that to verify the solution by using DGS. I believe that one needs to know exactly what he is going to construct with the DGS.

> **Both sequences combined**
> I think that it is better for one to combine both ways, namely, the formal explanations and practice with DGS. I think that the formulation of a solution causes better understanding of the material, while the computer illustrates the problem and its solution.

As can be seen from the students' answers, there is no consensus on the question of the right order in which to use DGS, before or after formal explanations.

Besides analyzing the above data and soliciting comments to better understand the students' attitudes towards integration of DGS into the course, we analyzed their teaching evaluations as well. Here we present a few typical comments by students about the role of DGS in the course, taken from those evaluations:

> Integration of DGS helps to visualize the material and therefore to understand the subject.
>
> A variety of teaching methods contributes to understanding the material, which is very nontrivial.

The obtained results indicate the students' approval of using DGS in teaching constructions in geometry.

In addition, we present the following short summaries derived from the researchers' journal with respect to the three academic years in which we conducted our tests.

> **2003 academic year**
> The students consider DGS to be useless. They don't feel it can help them. Thus, I decided to obligate them to use DGS when performing assignments.
>
> I believe this is what should be done, but still feel there ought to be a long way to make DGS helpful.
>
> **2008 academic year**
> Some of the students approve of using DGS, but others do not feel comfortable with the tool. I see the advantages of DGS but I'm not sure that by using it I don't lose time for the lesson.
>
> **2011 academic year**
> The students approve of using DGS to a great extent. Sometimes, they even initiate usage of it when I intend to begin with formal explanations. I feel very comfortable with the tool, and don't consider it to be time-consuming.

Discussion

The results of the current study demonstrated that integration of a computerized environment affects both instructors and students. Furthermore, it was found that the changes in the course due to its adaptation to DGS affected the students' attitudes toward the role of a computerized environment in the classroom. Our findings indicated that the percentage of students who believed that DGS contributed to their learning increased as the course was adapted over time.

It is important to emphasize that the changes in the described course consisted both in merging a course on constructions in geometry with another course on the utilization of math software in teaching mathematics, and also in changing the pedagogical procedure, so that the lessons were planned based on extensive usage of DGS for a variety of purposes. The described changes are in good agreement with a number of relevant studies (Hooper & Reiber, 1995; Lawless & Pellegrino, 2007).

The students' responses indicated their ability to take advantage of the dynamic environment when the pedagogy of the course was entirely technology-oriented (Monaghan, 2001; Hollebrands, 2007). At the same time, the mission of the instructor is to bring to students' attention the fact that technology is not a panacea but only an auxiliary tool that can't be helpful without a profound knowledge of the subject (Cuban et al., 2001).

Our findings indicated that the students approved of DGS's contribution, which, to their mind, consisted in part of visualization of a problem – enabling them to see and therefore to understand it – but mainly of the possibility to investigate the problem under different conditions (i.e. to change the data and look for the corresponding solution, by taking advantage of the dynamic properties of DGS). At the same time, the students admitted that math software cannot help them to find the solution.

Another interesting finding has to do with the students' opinions about the best order in which to use formal explanations and practice with DGS. We observed that these opinions changed in Group 3 with respect to Group 2: more than half of the students in Group 3 stated that they preferred either practicing with DGS first or combining DGS with formal explanations, while almost half of the students in Group 2 preferred a traditional order – namely, formal explanations by the instructor first and then practice with DGS. This result might indicate that the more technology penetrates into pedagogy, the more diverse ways of learning might be provided to students, especially to those students that have difficulties with formal thinking.

We suggest that the results we obtained are due to the changes we made in the pedagogical procedure. Examining our experience of using DGS in teaching, we suggest that it is in good agreement with the five-phase model for adapting educational technology in the classroom (Hooper & Reiber, 1995). At the beginning stage, the adaptation of educational technology in the classroom consisted of occasional usage of technology for selected topics in the course.

Then, at a later phase in the course's evolution we tried to use DGS in the classroom. Then, at the next stage DGS becomes an integral part of the course. Finally, at the current stage, the lesson plan is changed due to the obtained experience of integrating DGS in the classroom. The students are encouraged to conjecture and explore each presented topic, theorem or problem. In this connection, it seems to us very important to emphasize that, according to our experience, one of the most critical aspects of integrating technology in teaching is the ability and willingness of the instructor to initiate and accomplish this process. Unless the instructor himself feels comfortable with the chosen technology and is convinced of its advantages, the integration can be neither fruitful nor accepted by students.

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Appendix: Attitudes toward Integration of DGS in "Constructions in Plane Geometry"

1. Does the DGS contribute to learning "Constructions in Geometry"? If it does, please explain the way in which working with the DGS contributes to problem solving during all stages of the solution:

1.1 Does the DGS serve as a means of visualization?
Yes/No Explain your answer

1.2 Does the DGS serve in looking for the solution?
Yes/No Explain your answer

1.3 Does the DGS serve in investigating the solution?
Yes/No Explain your answer

2. Which order do you prefer (mark the correct option):

Formal explanations by the instructor first, and then practice with the computer program.
Practice with the computer program and then formal explanations by the instructor first.

(Please explain and motivate your answers.)