THE INFLUENCE OF STYLE OF LEARNING ON PREFERENCES REGARDING AUXILIARY TOOLS AMONG STUDENTS OF MATHEMATICAL EDUCATION

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Abstract

The current research has to do with the preferences of students of mathematical education with regard to auxiliary tools when dealing with mathematical assignments. The results point to the influence of the style of learning on students' choice of auxiliary tools. Based on the students' comments, we suppose that a probable explanation for their preferences might be their lack of confidence in their own mathematics knowledge. The findings of the current research point to possible ways to effectively use various auxiliary tools, including modern, up-to-date technology, for students of mathematical education.

Integrating Auxiliary Tools into Math Class

Marton, Runesson & Tsue (2004) argue that only when we really know what learners are expected to learn, what students actually learn in situations in which we are inviting them to learn and why they do not learn in other situations can we build a logical rationale for creating a learning environment. They claim that the educator should focus on developing students' environment-related learning capabilities. Marton et al. (2004) suggest that the educator should construct appropriate situations that induce the learner to experience these situations, which can lead toward meaningful learning. Koehler and Mishra (2008) refer to the design of instruction during the integration of technology. They claim that the educator should look for effective ways of integrating technology, pedagogy and content knowledge.

It's obvious that the role of digital technologies has grown enormously during the last few decades. As a natural consequence, those technologies have penetrated into education. In education digital technologies include application programs, presentation tools, learning platforms and the Internet (Koehler & Mishra, 2008). Numerous studies that focused on integrating technology in mathematics education indicate that various tools have specific capacities, although each of them also has its constraints, and technologies usually are not unbiased. The instructor must be able to choose the most appropriate tool for each specific assignment. The main questions are how to take advantage of each tool in the most effective and creative way (e.g., Calder, 2011; Lagrange, Argitue, Laborde & Trouche, 2003; Pitard, 2011) as well as how to integrate it in the classroom (Harris & Hofer, 2009; Kosma, 2003; Miodusar, Nachmias, Tubin & Forkosh-Baruch, 2003).

Deaney and Hennessy (2011) discuss the importance of looking for an adaptive approach to harnessing technology that can address a wide diversity of individual differences encountered in a very mixed class of students. Salomon (1997) points to another important aspect of the integration of technology in education. He suggests that the mode of integration should be congruent to the pedagogical rationale. He also believes that the psychological aspect of such integration must be taken into account as well. Salomon & Ben-Zvi (2006) propose that when introducing technology one should pay attention to three important issues; namely, the integration of the technology must be value-added; the instructor must be aware of the nature of the students' learning; and the instructor must define consistent evaluation criteria.

The research question of the current work has been derived from the findings of our previous studies, which were concerned with the integration of technology into math teaching. Here we would like to specify the three principal circles of this integration. In the first circle, a separate course on teaching mathematics by using a computerized environment was taught in our department. It was observed that neither the instructors nor the students approved of this course. Based on this finding we came to the conclusion that it might be more appropriate to have students practice using the computer to study the same topics that they were studying in a math course (Gurevich, Gorev, & Barabash, 2005). Therefore, the second circle of technology integration was teaching in parallel a discipline course and a course on using technology in math teaching which covered the same topics and even assignments. The effectiveness of such a layout was tested using the discipline course "Plane Transformations and Constructions in Geometry" in parallel with the course "Computer Usage in Math Teaching" (Barabash, Gurevich & Yanovsky, 2009). In the third circle of developing a course that integrated technology, we came to the conclusion that it might be much more effective to merge these two courses, and we did so with the above mentioned "Plane Transformations and Constructions in Geometry" (Gurevich & Gorev, submitted for publication). The results of this study show that this new layout improved both students' usage of the computerized environment and their achievements.

Based on the results from our previous studies we decided to expand our experience to new digital tools like applets, various math applications for the computer and video. Our aim was to look for the best way of using these tools for various math courses as well as to provide our students (future teachers) with adequate knowledge and experience to manage them. Furthermore, we were interested in investigating what auxiliary tool from a range of various tools was preferred by students of mathematics education when dealing with assignments of various levels of difficulty under different styles of learning (including traditional formal teaching as well as self-learning situations). In addition, we wanted to learn what modes of usage of auxiliary tools were more typical to our students. Our basic goal was to progress in formulating a pedagogical procedure with respect to learning environments based on technological innovations (Salomon & Ben-Zvi, 2006; Marton et al., 2004).

Research Methods

The current research deals with the professional development of student teachers in the context of integrating technology into math classrooms, and can be characterized as action research (Baxter-Magolda, 2004; Cochran-Smith & Lytle, 2001). Carr and Kemmis (1986) define action research as a cyclic process consisting of planning, action, observation and reflection.

Population and Setting

The research population consisted of 12 first-year students in the educational program for secondary-school math teachers of the Math Teaching Department at Achva College of Education (9 women, 3 men, $M_{age} = 22.8$ years, age range: 18–36 years). The current research was conducted during the first semester of 2008-2009 on the basis of two courses, namely, "Analytical Geometry-1" and "The Power and Square Root Functions." All of the students participated in both courses. All 12 students had similar background in mathematics, typical to freshmen. They had more or less the same math expertise as other students who participated in previous cycles of this long-term study. These students had no previous experience with digital technologies in math classes.

During each of the two courses the educator integrated various digital technologies: math software (NoLimits, GeoGebra, Matematix), PowerPoint, videos and applets. In two selected lessons of each course the students practiced using the above tools with given assignments.

In the first course the students learned one selected topic through self-study, and for their final project they were asked to solve a few problems on this topic. In the second course all topics were taught in the classroom. In both courses the final projects included problems of various levels of difficulty. For each final project the students were supplied with references to relevant Web sites that could help them with the assignments.

Data Collection

For the purposes of triangulation and reliability, the data were collected with the following tools: a questionnaire with both closed and open questions (see the appendix); interviews with students (appendix); artifacts (students' final projects); and a researchers' journal documenting lesson-planning as well as discussions between the researchers. The study consists of quantitative and qualitative analyses, where the qualitative findings can serve as explanations for discussions of the quantitative results.

Data Analysis

In the quantitative analysis, the students' answers to the questionnaire were evaluated with respect to type of tool, style of learning and difficulty level of problem. Frequency tables were made and the mode values were found.

In the qualitative analysis we performed content analysis on the data (Denzin & Lincoln, 2005), with respect to preferred auxiliary tool and mode of usage.

We grouped the relevant comments for each category (Tracy, 2010), and then performed targeted descriptive analysis (Shkedi, 2011).

Findings

In Table 1 we present the results indicating the auxiliary tools preferred by the students, evaluated with respect to style of learning, difficulty level of problem, and type of tool.

Table 1

Preferred Auxiliary Tools According to Style of Learning, Type of Problem and Type of Tool

Relatively Difficult Problem		Simpler Problem		Type of Problem
Self-learning	Learning in classroom	Self-learning	Learning in classroom	Style of learning / Type of tool
16	22	23	14	Mathematical software
7	3	11	3	Applets
37	7	39	11	Written materials (books, Internet, PowerPoint) and videos
In summary:				
1. Written materials 2. Mathematica l software	1. Mathematical software 2. Written materials	1. Written materials 2. Mathematical software	1. Mathematical software 2. Written materials	The two most preferred tools

We can see that the type of problem (simpler vs. relatively difficult) does not affect students' choice of preferred auxiliary tool. However, the style of learning does affect their choice.

The results indicate that the first preference of students performing their final project after self-learning was written materials, whereas their second preference was mathematical software. In the case when the final project was performed after learning in the classroom, the students' order of preference was found to be the reverse. Applets were found to be much less preferred by students compared to these other tools.

In Table 2 we present the results with respect to two relatively frequent modes of usage of the two types of auxiliary tools that were found to be preferred by students under both styles of learning.

Table 2.

Modes of Usage of Auxiliary Tools According to Style of Learning

For Problem Understanding		For Problem Solution		Mode of Usage
Self-learning	Learning in classroom	Self-learning	Learning in classroom	Style of learning / Type of tool
9	21	10	17	Mathematical software
14	4	18	9	Written materials

The results indicate that under the "learning in classroom" style, the students preferred to use mathematical software for both understanding and solving problems. Under the "self-learning" style, the students preferred to use written materials for understanding and solving problems.

Besides analyzing the above data and aiming to better understand the students' attitudes towards the integration of technology into math courses, we analyzed the students' comments as well. Below we present a few typical comments by students. The students explained their choice of preferred tool and the way they used it to deal with the assignment within the same comments. We didn't find any differences in the students' responses with respect to the level of difficulty of the problem.

Students who used the "self-learning" style wrote that they used mostly written materials (books, written materials from the Internet, computer presentations) when looking for theoretical explanations and solved examples. In addition, it can be seen from their answers that they integrated mathematical software and applets as well.

Here are some quotations:

> I used written materials – textbooks – since the topic, hyperbolas, had been given for self-learning. In books I looked for general explanations related to the given questions (1-3). In this way I tried to understand the topic in general and the given questions in particular, in order to solve these problems.
>
> GeoGebra helped me a lot to see the problem and to understand what was required in the question by means of plotting. The textbook helped me a lot in my general approach to the question. I used the second applet in order to draw various hyperbolas, and it helped me with the particular question. In addition, this applet helped me to understand the influence of the parameter on the graph of a hyperbola. The first applet helped me too by means of visualizing an isosceles hyperbola, both to understand the influence of the parameter and also with the drawing.

> I had to combine textbooks and computer demonstrations of G-Math and GeoGebra, since the visualization helped to assimilate the material, especially because we learned the topic of hyperbolas by ourselves. When using the program I saw the difference between an ellipse and a hyperbola, which helped me to solve the assignment.

The above discussions point to the choice of multiple auxiliary tools by students when dealing with the solution of problems. In order to understand more about the way the students worked, we held interviews with all the students who participated in the course. Here we present only one typical interview, since all the students mentioned the same auxiliary tools, though in various orders. All of them emphasized that they mainly used the written materials, but also math software and applets:

> Various auxiliary tools helped me to understand the problem and then to solve it. First, I read different written sources and then I tried to draw relevant plots in order to make sure that I understood the material in the right way. Finally, I used GeoGebra.

Under the "learning in classroom" style, the students used dynamic geometry software to a great extent, mainly in order to understand and solve the problem. For example, one student commented, "I used the graph-generator, No-Limits and GeoGebra for questions 1-3. These tools permitted me to understand question 4 as well".

We found that under the "learning in classroom" style, the students used various auxiliary tools as well, mainly for the presentation and verification of solutions. From the students' answers to the open part of the questionnaire, it can be seen that they used a variety of auxiliary tools for various purposes. Still, it is apparent that the preferred tool was mathematical software, while the applets and written materials were used as well:

> In this question I made use of GeoGebra in order to understand the question and then to solve it. In addition, I used the worksheets with the solutions of the problems that we had solved in class.

Next we present a short summary of just one typical interview, since most students in this group indicated that they preferred the same auxiliary tools – namely, math software, textbooks, worksheets from the Internet and applets – as well as various ways of using them in working on the final project.

> I used GeoGebra for problem solving by the trial and error method. For example, I drew various function graphs and checked the number of points of intersection in each case. This tool is very important and useful. I was glad to get acquainted with it. Within a few seconds one can see the drawing.

In summarizing, in order to illustrate the integration of graphs and algebraic solution, we present in Figure 1 an example from one student's assignment:

The ellipse and the hyperbola are tangent to each other when they have the same value of *a*

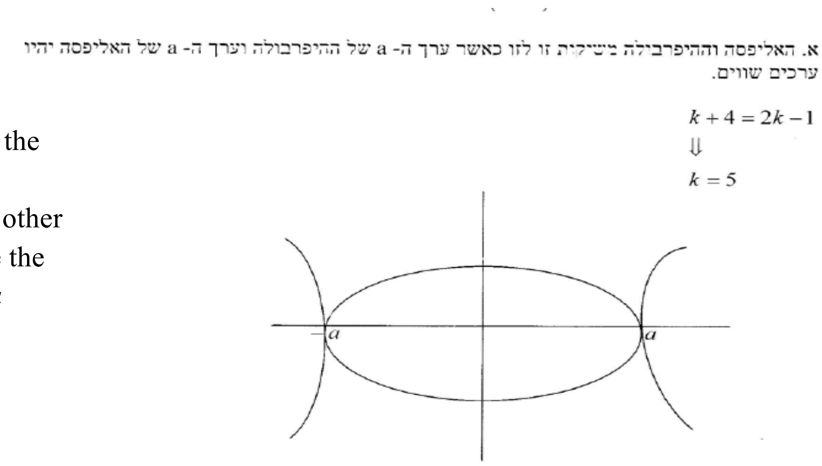

Figure 1. An example of both formal and computerized solution.

Discussion

The quantitative results of our study indicate that under the "self-learning" style, students preferred to use written materials as an auxiliary tool. Based on the students' comments, we suppose that a probable explanation of their preferences might be their lack of confidence in their own mathematics knowledge. As far as the "learning in classroom" style is concerned, we observed that these students preferred math software. A possible explanation might be that these students were confident in their knowledge and the visualization properties of math software permitted them to see the whole picture. The quantitative part of the research aimed to identify the students' preferred auxiliary tool from a variety of technological tools. However, as a result of our research's limitations - the number of participants was too small for generalization, and the integration of auxiliary tools into teaching was checked in only two courses – we added a qualitative part to our research.

Although the above results point to students' having certain preferences regarding auxiliary tools, their comments indicated that they actually combined several auxiliary tools, and that each of them chose his/her own strategy for using those tools, with consideration for the capacities and constraints of each one. The students' comments demonstrated creativity in the ways that they used and combined various tools for different purposes. These observations are in good agreement with findings from several recent studies (Calder, 2011; Lagrange, Argitue, Laborde, & Trouche, 2003; Pitard, 2011). We suggest that the students were able to benefit from such a strategy especially because they were familiar with all the presented tools within their everyday life. Furthermore, we observed that the students enjoyed the dynamic features of the presented technological tools and therefore they were ready to accept, adopt and take advantage of them.

We agree with Marton et al. (2004) that when integrating new technologies into teaching, the most critical issue is the appropriate and optimal organization of the classroom. We suggest that the optimal way to organize the learning environment is to provide the students with the full variety of appropriate auxiliary tools by emphasizing all their advantages and disadvantages. In this way, the instructor only supplies the students with various learning opportunities, without insisting on any specific strategy. We believe that teacher educators should keep abreast of the new technological tools and integrate them into their lessons in order to serve as examples for their students. In addition, in our experience, we found that the instructor should match the assignments and tools in a rigorous way in order to contribute meaningful learning. Among our findings from the current study, we observed that the students did not choose applets as their first preference of auxiliary tool, in spite of the fact that we tried hard to fit them to the proposed assignments. We suggest that this result might be a subject for more detailed examination.

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Appendix

Questionnaire

1. What kind of auxiliary tool did you prefer when solving the problem? Explain your choice.

2. What was your mode of usage of the preferred tool? Explain your choice.

Interview

Please describe the way you integrated the auxiliary tools while solving the problems. Explain your chosen method.