PRE-SERVICE TEACHERS' TRANSITION FROM"KNOWING THAT" TO "KNOWING WHY" VIA COMPUTERIZED PROJECT-BASED-LEARNING

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The aim of the study was to examine the effects of implementing computerized project-based-learning (CPBL) approach into a didactical course for third year pre-service mathematics teachers. In this paper we focus on impacts concerning the pre-service teachers as learners. Analysis of the data revealed three main sub-categories relating to aspects concerning the pre-service teachers as learners: the development of self-confidence in mathematical competence; the contribution of the computerized environment; and the impacts of the classroom discussions. We give evidence to the students' transition from "knowing that" to "knowing why" the CPBL approach is a promising learning/teaching method for turning the mathematics experience into an exciting and challenging one.

INTRODUCTION

Calls for reforms in mathematics education (e.g. NCTM's standards, 2000) emphasize the importance and the advantages of teaching through problem-based-learning. Our experience shows that although in-service teachers are exposed to innovative teaching methods, they tend to avoid employing them in their classrooms. Informal interviews with teachers revealed that the main reason for this phenomenon is that although they are familiar with new methods, they do not have the required confidence for incorporating them into their teaching framework. Moreover, the teaching and learning processes that are involved seem to them rather vague. We believe that in order for teachers to become aware of the various processes associated with methods such as problem-based-learning, they should experience it themselves for a long period of time. We assume that such an experience would help teachers assimilate it into their pedagogical content knowledge (PCK) and consequently will be motivated to try this method in their classes.

BACKGROUND

Many researches agree that PCK is an essential component of teachers' knowledge (e.g. Even & Tirosh, 1995). PCK consists of knowledge about the subject matter and knowledge about students. The latter refers to decisions concerning teaching methods and strategies.

Obviously it is impossible to reach an agreement regarding what should be the constituents of PCK and what are the appropriate approaches that should be taken in order to convey them. It is clear that each teacher/educator chooses his/her approaches in accordance to former experience. We believe that experiencing new teaching methods such as project-based-learning (PBL) in general or computerized project-based-learning (CPBL) in our case, would promote both the subject matter and knowledge about students.

A PBL is a teaching and learning strategy that involves students in complex activities, and enables the learners to engage in exploring important and meaningful questions through a process of investigation and collaboration. Via PBL students ask questions, make predictions and decisions, design investigations, collect and analyze data, use technology, share ideas, build their own knowledge by active learning, and so on (Krajcik, Czerniak and Berger, 1999). PBL enables students working relatively autonomously over an extended period of time and ending with products or presentations (Jones, Rasmussen & Moffitt, 1997; Thomas, Mergendoller &Michaelson, 1999). As a consequence, concepts of the discipline are learned through the process of project conducting.

Research (e.g. Krajcik et al, 1998) points to various advantages of PBL: it develops a sense of personal contribution to the process of learning; increases motivation; raises the self satisfaction; helps in developing long-term learning skills and a deep, integrated understanding of content and process; involves cooperating with each other and hence increases the ability to share ideas in order to solve problems; promotes responsibility and independent learning; engages students in various types of tasks, thereby meeting the different learning needs of many different students; develops the ability of collecting and presenting data, etc.

There are many advantages to integrating computer software into the setting of PBL. Among them: it enables the students to make experiments, observe stability/instability of phenomena, state and verify conjectures easily and quickly, etc. (Marrades & Gutierrez, 2000).

Students might also encounter several difficulties while learning in PBL approach. Among them: inability to generate meaningful questions; trouble in managing complexity and time; problems in processing data and developing a logical argument to support claims (Krajcik et al., 1998). According to the authors, those findings point to the need for incorporating a range of "scaffolds" within the PBL process in order to help students overcome their deficiencies.

Research show (e.g. Greens & Schulman, 1996) that classroom communication can serve as suitable "scaffolds": *“Communication is essential to students' successful approach to, and solution of, mathematical explorations and investigations. Students must communicate with others to gain information; share thoughts and discoveries; brainstorm, evaluate and sharpen ideas and plans; and convince others”*.

The present study examines the impacts of implementing the CPBL approach combined with classroom discussion into a didactical course for mathematics PST.

THE STUDY

In the current study we examine the effects of integrating a CPBL into an annual course named "Didactical foundations of mathematics instruction" for PST of mathematics. This course focuses on theories and didactical methods implemented in teaching and learning geometry (in the first semester) and algebra (in the second semester) in junior high-school. 25 college students (8 male and 17 female students) in their third year of studying towards a B.A. degree in mathematics teaching participated in the research. This course is the second didactical course they were participating in. The previous one was taken in their second year of studying.

In our study we attempt to characterize the various processes PST experienced while engaging in CPBL. In this paper we focus on aspects relating to the students' experiences both as mathematics and didactics learners

In order to clarify what we mean by CPBL and what we believe should be its phases; we exhibited a ready-made project, which was based on Morgan's theorem (Watanabe, Hanson & Nowosielski, 1996). Afterwards the students had experienced CPBL, which included the following phases: (1). Solving a given geometrical problem, which served as a starting point for the project; (2). Using the "what if not?" strategy (Brown & Walters, 1990), for creating various new problem situations on the basis of the given problem; (3). Choosing one of the new problem situations and posing as many relevant questions as possible; (4). Concentrating on one of the posed questions and looking for suitable strategies in order to solve it; (5). Raising assumptions and verifying/refuting them; (6). Generalizing findings and drawing conclusions; (7). Repeating stages 3-6, up to the point in which the student decided that the project has been exhausted.

The research data included: (a). Transcripts of videotapes of all the class sessions. (b). Two written questionnaires. (c). Students' portfolios that included a detailed description of the various phases of the project and reflection on the process. (d). Informal interviews.

During the class sessions the students raised their questions and doubts, asked for their classmates' advice, and presented their work.

The students could choose to work individually or in pairs. They used dynamic geometrical software in the various stages of the project.

RESULTS AND DISCUSSION

Analysis of the data obtained from the transcripts, questionnaires, portfolios and interviews revealed a remarkable impact on students' views and attitudes that are connected with the learning and teaching of mathematics. In this paper we focus on some of the changes that emerged during the work on the project regarding didactical aspects.

Analysis of the data points at three main sub-categories relating to aspects concern with the PST as learners: the development of self-confidence in mathematical competence; the contribution of the computerized environment; and the impacts of the classroom discussions.

The development of self-confidence in mathematical competence-

Most of the students stated that they had changed their view as regards "what is mathematics" and what can be considered as "doing mathematics". At the beginning of the course, most of the students perceived the mathematics as a domain in which they had to act according to rigid given rules. They believed that the mathematicians' task is to formulate regularities and to create problems and their assignment is to prove and to solve them. By the end of the course most of the students felt differently:

"I changed my perception of mathematics in 180^0. I am surprised by myself "; "I discovered many interesting things that I did not previously think of. Things that were beyond my expectations"; "New ideas came into my head regarding how to begin the thinking on new problems and how to cope with them"; "The work on the project raised my motivation to investigate and discover mathematical regularities, pose new problems and not accept anything as obvious"; "The work on the project helped me realize that not everything in mathematics is black or white, and that you can have fun while doing mathematics".

As the students were asked to clarify their statements, we noticed a conceptual change in their thinking, one that implies a shift from perceiving themselves solely as mathematics learners to "mathematics makers" as well. While as mathematics learners their "mission" is to solve given problems, or to prove already known theorems, as mathematics creators they become part of the mathematical community by being able to pose new problems and find new mathematical regularities.

This change of view caused many students to explicitly distinguish between the traditional methods of learning mathematics and the CPBL approach, and stated that their ability to discriminate between them was a kind of insight they gained from working on the project:

"…when I need to prove a mathematical regularity, I know that the regularity is valid and all I have to do is to prove it formally. Whereas working on the project was accompanied by different feelings. The search for regularities, that might not exist, raised doubts and fears but also curiosity and motivation".

The above quotation points to a very important aspect, which is fundamental to the conceptual transition from implementing traditional methods of problem solving in which the learner does not question the validity of the problem to posing new problems whose validity is questionable.

Along with the feelings of lack of confidence, which were expressed by raising doubts and a sensation of "fear", there were curiosity and motivation.

Students report that the recognition of their ability to find new regularities and not just work mechanically changed their self confidence in their mathematical competence:

"…The important thing is that I am capable of finding new things. It is true that what I had found is not very interesting to the mathematical community, but who cares? The fact that I am working and thinking of what to do next – this is new to me".

This student, like many others, found out that the process of doing mathematics became more significant to her as she was no more solely "results oriented".

Apart from the students who benefited from the activity, there were three students who did not feel any change during the period of working on the project. Moreover, they explicitly expressed their resentment, since we insisted that they continue their work. Interviews with those students revealed that they found it very difficult to work in a different manner from the one they were used to. After a few attempts to find "interesting regularities" with no success, they gave up and lost their motivation to keep on looking.

The contribution of the computerized environment

Most of the students were not used to utilizing computer software for discovering unfamiliar mathematics facts. All the students found that the usage of the dynamic geometrical software had a major impact on their work:

"*Without the software I would not have progressed in the project"; "The software enabled me to find a proper method for working on the project; everything is in front of your eyes"; "The software directed me to think completely differently"; "Things can be discovered not just by using formulas and theorems but also through self investigation using the software"; "The software helped me to think in various directions to discover new facts which I could not think of by myself"; "The software influenced the investigation route. Since the software does all the technical work, all I have to do is to think. It is easier. If I had to do the whole work by myself – I would probably give up"; "The software made the inquiry process more qualitative, quick and efficient and thus the probability for new and surprising discoveries to emerge was raised"*.

From the above quotations it can be seen that the students believe that unless they had carried out their project via a computerized environment they would not have reached so many mathematical regularities. The software provided them the freedom of thinking about *"what questions should I pose and how should I test them"* rather than wasting energy in performing a Sisyphean task such as computations and drawings. This kind of learning was new for them, especially the insight that they can regulate their own learning and modes of thinking. The fact that they could easily create new problem situations and visualize them facilitated their work and enabled them to elaborate their investigations.

An important aspect of using the software was raised by the students:

"Working with the software provided me a sense of 'a proof in front of my eyes'. I will never forget it. No doubt that the formal proof is required but visualizing the proof is not less important".

As was stated before, the students were familiar with the accepted routine in which they were given a statement, already known to be valid, and their task was to provide a formal proof. Since during the work on the project they had to raise their own hypothesizes and to test them, the software provided them a sense of "security". They felt that they can see a "visual proof" to what they had just discovered, and thus they were motivated to prove it by formal means.

The impacts of the classroom discussions

The main purpose of the classroom discussions was to provide the students the required "scaffolds", which were previously mentioned.

Most of the students emphasized the impact of the classroom discussions on their progress in the project. Students reported that their classmates' presentations encouraged them to keep on looking for "interesting" regularities. When they were asked to define what are "interesting regularities" they said that this should be *"something new - something that I did not know before"*.

One of the most significant findings was that the presentations set "normative standards" to what should be considered as an "interesting discovery". These standards went higher and higher as time passed.

During the presentations, many original ideas were raised by the students and assisted the members of the group that presented the work to articulate their findings. Additionally, it often caused them to think of alternative ways of investigation. Moreover, the rest of the students also benefited from the process since the new coming ideas caused them rethink possible alternatives for their own projects.

“Observing the presentations of my classmates helped me think how to alter and expand my project”.

In fact, through the classroom presentations the students were simultaneously thinking in both directions: how to help their presenting mates to find new ideas, and how to assimilate those ideas into their own project.

Even the three mentioned students, who had difficulties coping with the project, found the discussions to be very helpful:

“I found the discussions to be helpful for me since together we succeeded to prove things and to learn a lot of geometry. It is nice that everyone contributes a little bit and together we learned a lot”.

Students also related to our role, as the classroom instructors, in monitoring the discussions. They said that even in situations in which it looked as if no "valuable" results would emerge, the fact that we instructed them to probe for alternative problems, eventually led them to discover new directions of investigation.

The discussions also had a "side effect" which we did not anticipate: some of the discussions had a negative impact on part of the students, especially those who were slightly disappointed by not yet finding "interesting findings". Instead of being encouraged, they got the feeling that they will never be able to reach the normative standards that were informally established.

CONCLUSIONS

Since all the students had already taken a didactical course in their previous year of studying, when they began the present course they were already familiar with the concepts "investigation activity" and "problem-based learning". They all knew that it is important to employ such methods in the classroom, but they did not really know why. Therefore, based on our prior experience, we can assume that the chance that they would choose to integrate the methods into their future classrooms was probably low. Experiencing the processes that are involved in employing the methods, via CPBL, enabled most of them to understand the "why" aspect. We can presume from the various data resources that they now realize that learning through problem posing encourages the development of self-confidence in mathematics competence, develops mathematical qualifications, and turns the learning process into an exiting and challenging one. *:*

*“ **I am sure** I will adopt this method to be used in my mathematics classrooms and I will also use the method for looking for connections between mathematical regularities”; “**I***

want *my students to go through the experience we had…"; "****now I know that**** *as part of the mathematical proof it is important for the students to see why the statement is true, as we did it in class"; "working on the project made me understand why it is important to encourage students to work on exploration tasks and to discover by themselves the mathematical regularities instead of getting them as obvious"; "* ***I know now for sure*** *that there is a need to show the mathematics and not just to teach definitions and formulae ".*

FINAL REMARKS

It is not often that we, as teachers' educators, get to hear: "*…Everything was so intriguing and exiting…When we had the feeling that we were finally reaching something, we kept checking it with the aid of the computer just to be sure. At those moments we were tense…We were afraid to discover that it is not always true… I could hear my heart beats strongly …Only after we discovered that we were right, a huge smile spread slowly on my face…I felt real joy and pride, and my confidence rose…But this feeling did not cause me to rest, it only motivated me to think of another problem, one that would be even more interesting*". We must admit that while reading those sentences a huge smile spread slowly on our faces. This was our benefit from the process they had experienced.

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