PRE-SERVICE MATHEMATICS TEACHERS' PRACTICE OF QUESTIONING IN COMPUTER LEARNING ENVIRONMENTS [1]

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This paper focuses on a specific aspect of formative assessment, namely questioning. Given that computers have gained widespread use in learning and teaching, specific attention should be made when organising formative assessment in computer learning environments (CLE's). A course was designed aiming to develop knowledge and skills of questioning in CLE's for the purpose of formative assessment. This case study investigates how a pre-service mathematics teacher used questioning in the classroom to introduce the derivative concept using Geogebra and Graphic Calculus software. The findings indicated that the course provided a guideline for pre-service mathematics teachers in planning and using effective questioning in CLE's.

INTRODUCTION

Assessment plays an integral role in teaching. However, as Heritage (2007) point out, assessment and teaching have been traditionally seen as reciprocal activities as a result of measurement concerns such as high-stakes accountability of testing. Many researchers mention that good practice yields from a recognition of both summative and formative purposes of assessment and use them accordingly (Dwyer, 1998).

Despite its importance for learning and teaching, assessment has not been a main focus of teacher training courses. Furthermore, administrators "also lack training in assessment and therefore do not have the skills to support the development of assessment competencies" (Heritage, 2007, p. 4). Dywer (1998) mentions that, courses on evaluation of learning have been disappearing from teacher education programs. However, she claims that it is well understood by experienced teachers and assessment is well targeted in many professional development programmes for in-service teachers (Danielson, 1996 as cited in Dywer, 1998).

Given that computers have gained widespread use in learning and teaching, specific attention should be made when organising assessment in computer learning environments (CLE's). A successful integration of technology into instruction requires an integration of technology into assessment. On the other hand, there is little research on how to organise assessment as an integral part of teaching in computer learning environments (Kissane *et al*., 1996).

Considering the need to incorporate assessment component into pre-service teacher education programs and the importance of integration of technology into instruction as suggested by the relevant literature, we designed a course for pre-service mathematics teachers, which aims to develop their assessment skills as a component of TPCK. This paper focuses on how a pre-service teacher developed the knowledge

and skills of formative assessment in computer learning environments. Particular attention is given to questioning which occur during classroom assessment.

THEORETICAL FRAMEWORK

In teacher education research, assessment has been considered as an important component of teachers' knowledge of pedagogy. After Shulman (1986) suggested pedagogical content knowledge (PCK) as a separate domain of teacher knowledge, many researchers such as Tamir (1988) defined assessment as a component of PCK. Pierson (1999) and Mishra & Koehler (2006) has added the technology component to PCK framework and defined Technological Pedagogical Content Knowledge (TPCK) framework. Although, in the literature, the components of the TPCK framework have been defined as parallel to the components of PCK framework, assessment as a component of TPCK has not been sufficiently dealt with.

The theoretical perspective of this study is situated within the distinction between summative and formative purposes of assessment. Summative assessment is used for the purpose of grading or certifying students. On the other hand, formative assessment intends "to monitor student progress during instruction to identify the students' learning successes and failures so that adjustments in instruction and learning can be made" (Gronlund, 2006, p. 6). There is research evidence of the extraordinary effectiveness of formative assessment (Black & Wiliam, 1998). Despite its importance, most pre-service teachers use assessment for summative purposes while a minority uses for formative purposes (Volante & Fazio, 2007). There are various aspects of formative assessment: uses of tests to diagnose what students have already known or using the evaluation of homework in decision making for the next lesson and classroom assessment which occurs in the classroom on a daily basis. Among those, researchers point out classroom assessment as an area of difficulty which is encountered by pre-service teachers (Mavrommatis, 1997).

Classroom assessment refers to the processes of collecting information and making interpretations and decisions based on this information on a daily basis in order to improve teaching and learning (Airasian, 1991 as cited in Mavrommatis, 1997). In that process, questioning is an important information-gathering technique by which teachers can monitor student learning. Airasian & Jones (1993) claim that pre-service teachers are not given adequate training in developing questioning strategies and, indeed, that some receive no training at all. Therefore, questioning that can facilitate formative assessment for the purpose of learning should receive more attention in the preparation of teachers.

Given that computers have gained widespread use in learning and teaching, specific attention should be made to questioning in CLE's. Therefore, this study focuses on the design of a course aiming to develop knowledge and skills of questioning in CLE's for the purpose of formative assessment. To analyse pre-service teachers' questioning, Pierce & Stacey's (2004) framework is adopted. Their framework

identifies the main characteristics of students' interactions with CAS technology. They specify aspects of effective use of CAS which they suggest to adopt to other mathematical software tools. Using a CAS in particular or any other software in general to do mathematics requires both traditional mathematical knowledge and knowledge of the machine. These two requires a constant interplay which Pierce & Stacey (2004) defined as *technical aspect* of effective use of technology which could be described as the knowledge and skills related to the software rather than the hardware of the machine. It is where mathematics meets machine (e.g. fluent use of software syntax, ability to systematically change representation or interpreting the software output) as mentioned by Pierce & Stacey (2004).

In the framework, two types of questions will be distinguished. The first is *mathematical questions* which aim to assess what Pierce & Stacey (2004) call traditional mathematical knowledge. The second will be called *technical questions* which attend to technical aspects of using technology. Although questions in this category seem to focus on what the software perform, there is a constant interplay of mathematical knowledge and knowledge about the technology (See Figure 1).

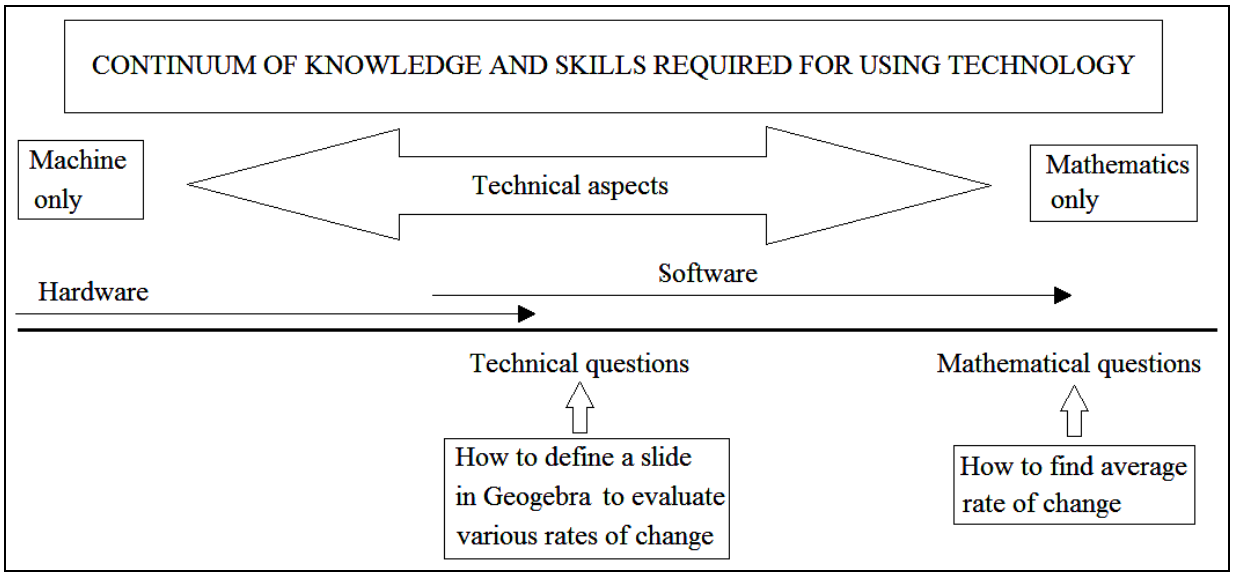

Figure 1: Continuum of knowledge and skills required for using questioning in CLE's

The aim of this paper is to explore what kinds of issues come into question in CLE's in terms of questioning for formative purposes. In this respect we formulate the following research question: "How do pre-service mathematics teachers use mathematical and technical questions for formative purposes in CLE's?

COURSE DESIGN

In a wider context, this study is part of a research project for which we designed a course guided by TPCK framework. In this paper, the description of the course is restricted to its assessment component. An eight-hour workshop was conducted on assessment. During the first phase, which we call PCK workshop, general information on assessment, its integral relationship with learning and teaching, and

examples of summative and formative assessment was given. This is followed by activities during which forty pre-service teachers worked in groups. In the first activity, pre-service teachers were asked to specify objectives of a lesson which introduces the concepts such as function and derivative. They presented their objectives to their peers and discussed each group's objectives in an interactive way. For the second activity, they designed lesson activities to achieve their objectives. As they began to structure their activities, they were asked to prepare questions to provoke student thinking for the purpose of attaining their lesson objectives. The aims of such questioning in a lesson were explained in relation to classroom assessment for formative purposes. At the next phase, which we call technological knowledge (TK) workshop, pre-service teachers learnt how to use computer software and did hands-on-activities in a computer lab in groups of twenty. They used Graphic Calculus, Geogebra, Probability Explorer, Excel and Cabri Geometry software. This phase focused on the technical knowledge of the software. The last phase, which we call TPCK workshop, focused on the pedagogy of using technology with specific attention given to the assessment component. Focusing on the content, that is function and derivative, pre-service teachers were asked to re-consider their lesson activities and how to attend to assessment of their lessons. They also practiced various computer based assessment tools such as dynamic worksheets of Geogebra and Inspiration software for making concept maps. During this phase, we focused on the following questions with regard to assessment in general and questioning in computer learning environments in particular:

- How would assessment and evaluation techniques/tools change when concepts such as function and derivative are taught using technological tools?
- How can technology be used for summative/formative assessment to achieve lesson objectives which you specified for the lessons for function and derivative concepts?

Questions above were discussed with pre-service teachers during the workshops considering a specific lesson objective as shown below:

Let us consider the following lesson objective: • Students will be able to express derivative at a point as instantaneous rate of change. To assess whether this objective is achieved by students, ask questions with the following purposes: • What kinds of questions could be asked during a lesson in CLE's for summative/formative purposes to promote thinking in accordance with lesson objectives?

Table 1: Points of discussion concerning questioning during the workshop

Following this, workshops focused on classroom assessment in CLE's and how to evaluate students' understanding when they use technology. We emphasised that the

nature of probing questions will be changed as a result of change of media in the classroom. Pre-service teachers were encouraged to ask questions on what were performed by the software and their mathematical meanings to promote purposeful use of technology.

METHODOLOGY AND CONTEXT OF THE STUDY

This study is part of a research project which aims to develop a programme for pre-service mathematics teachers guided by TPCK framework. The research has been carried out in a mathematics teacher education program in a state university in Istanbul, Turkey.

Following the TPCK workshop which was explained in detail above, pre-service teachers were asked to prepare lesson plans which introduced the concepts of function and derivative at a point as the first part of the program. In these lesson plans, they were also asked to explain what kinds of assessment they plan for their lessons. Ten pre-service teachers taught these lessons as part of micro-teaching activities and discussed their assessment approaches with their peers. This way, pre-service teachers had the chance to put their knowledge of assessment into practice. In the second part of the program, pre-service teachers planned and conducted their own workshops of TPCK on various mathematical concepts such as limit, continuity, integral, probability and radian and did micro-teaching activities.

For the current exploratory study, a case study was conducted to investigate a pre-service mathematics teacher's practice of questioning for the purpose of formative assessment in CLE's. The pre-service teacher, Güven, is male and twenty-two years old. He completed mathematics courses which lasted for three and a half years and started to take education and mathematics education courses. The data was collected during "Mathematics Teaching Methods II" and "Instructional Technologies and Material Development" course. Pre-service teachers participated in the program were asked to prepare a lesson plan with detailed teaching notes to introduce the concepts of function and derivative and they were interviewed on their lesson preparations. Semi-structured interviews, which included a section on how assessment is planned, were conducted. In addition to that, pre-service teacher's lesson and his reflections at the end of the lesson were video-taped. This paper focuses on the analysis of Güven's lesson plan, verbatim transcripts of his interview on the preparation of his lesson plan, and video of his micro-teaching lesson on derivative.

FINDINGS

In this section, findings will be presented in two sub-sections. The first sub-section focuses on how Güven planned to use questioning for formative purposes in his second lesson plan on derivative at a point which he prepared after the TPCK workshop. In the second sub-section, findings from the analysis of Güven's lesson will be presented with excerpts demonstrating his questioning in the classroom.

Güven's planning for questioning

Güven included the following problem in his lesson plan to start his lesson:

> *Engineers who design car templates are working on the highest velocity that the template is going to reach after two seconds. They evaluated the distance during the first five minutes and they represent it with the function* $f(x) = x^2$.

During the interview, he mentioned that he chose this problem to create a cognitive disequilibrium. He also added that he would use a lot questioning to start a discussion on the problem in the classroom.

Güven's lesson plan draft included two sub-sections on assessment: assessment during the lesson and assessment at the end of the lesson. Güven wrote a few questions to be asked during the lesson for two different purposes: diagnostic purposes and formative purposes. For formative purposes, he mentioned that he would check whether students (that is their peers) had learnt what he intended to teach using these questions. Some of these questions in his plan were specific to the software he used, namely Geogebra and Graphic Calculus. One example of these is the following: "How does Graphic Calculus calculate the values for rate of change? Find one of these values with paper and pencil". During the interview he said the following:

> Güven: The formative questions that I prepared were related to the activities that were performed on the computer. Students (his peers) performed these activities by looking at the computer and making calculations.

As can be seen from the question in his lesson plan and excerpts above, Güven purposefully planned for formative assessment. The question above can be considered as a technical question since it requires both the knowledge of how to evaluate the values of rates of change and the knowledge of the software.

Güven's practice of questioning

In practice, Güven used a lot of questioning for formative purposes during his micro-teaching lesson which he taught to his peers. Below, a detailed account of his questioning approach during his lesson is presented. Strength and weaknesses of his pedagogical approach to using mathematical and technical questioning will be discussed below.

In the computer lab his peers were in front of the computers in pairs. Güven started his lesson with the problem above. After asking questions about velocity and instantaneous velocity to assess their prior knowledge, Güven asked his peers to find the average velocity in the first two seconds which is $[f(2)-f(0)]/(2-0)=2$. Following this mathematical question, he asked how to represent the average velocity using Geogebra software which is a technical question. At this point, it should be mentioned that this question can be either solved graphically (finding the slope of the tangent line in the equation of the tangent) or numerically using spreadsheet view.

Instead of letting his peers to chose the representation to find the average velocity, he preferred to explain it on the graph using Geogebra. He then asked how to represent the average value on the graph by plotting two points on the graph which is again a technical question:

Güven: Did we specify two points, both (2,4) and (0,0). Are these, change in *y* divided by change in *x*? Let us check it again using Geogebra. But how?

He then mentioned that he would define rate of change using "slide" feature of Geogebra. Although he asked technical questions about how to do it, he immediately demonstrated it in a step by step manner without waiting for the class to do it in front of their own computers.

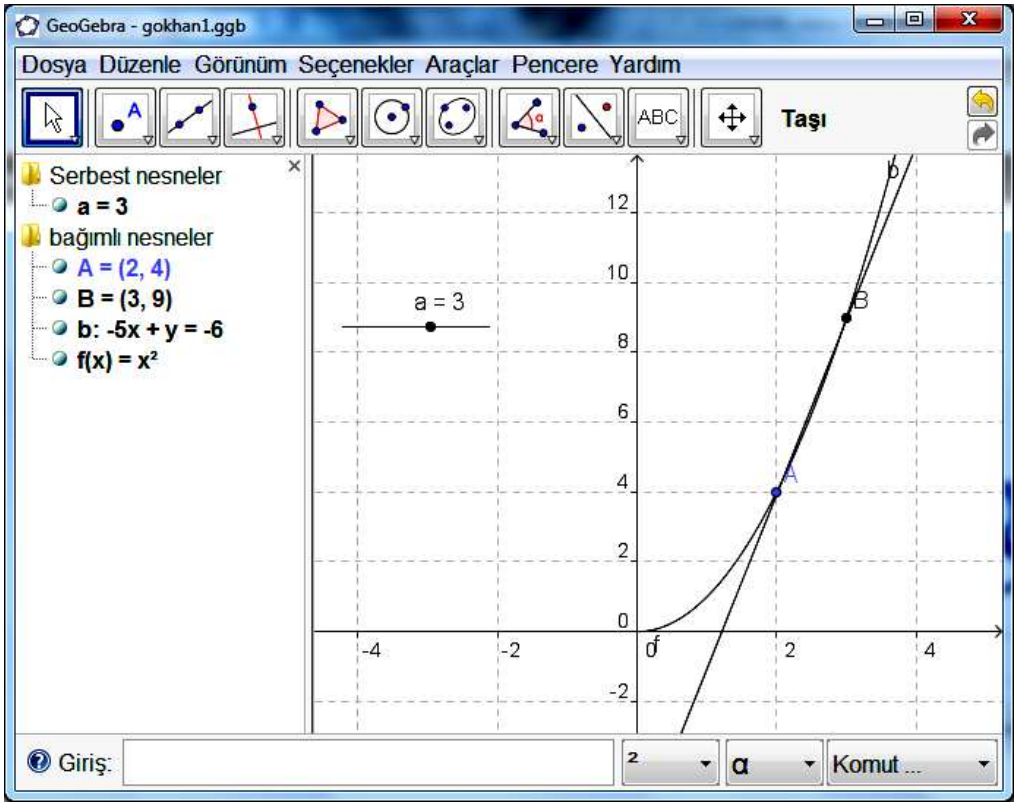

Figure 2: Geogebra activity used by Güven to explain graphical meaning of derivative

After obtaining the graph as shown in Figure 2 above, he asked the following questions to help his peers discover the relationship between average velocity and the slope of the chord:

Güven: What else can velocity between *A* and *B* be equal to? Let's think about it on the graph. Let's draw a chord from *A* to *B*. What would velocity be equal to in terms of the chord?

Student: Rate of change, slope

Güven: Well, we can draw a straight line through two points using Geogebra.

After that point he went back to the problem he asked in the beginning of the lesson and asked his peers to find the highest velocity in the first two seconds:

Güven: We chose two points for the average velocity. How can we find the velocity at a point? For instance, let's move your slide in Geogebra.

Student: We can't find it. It becomes undefined.

Güven: How did you choose the points to approach? Where does the point *A* approach to?

Student: To the point *B*.

Güven: When the points are on *B* it's undefined. Let's see it on the table.

As can be seen from the excerpts above, Güven asked questions to help his peers find the instantaneous velocity and told them to move the slide. In other words, using the slide feature of the software he wanted them to interpret the outcomes of the software and find instantaneous velocity. Therefore, his questions above can be considered as technical questions where the slide feature of Geogebra interplays with the knowledge of instantaneous velocity.

After that point, he focused on the table as well graph to explain the instantaneous velocity. To do that, he used the spreadsheet view of Geogebra and evaluated $\Delta y/\Delta x$ and asked his peers to interpret different values obtained on the table by moving the slide:

Güven: (Pointing out slide a). Is "a" at 0? Let's trace this point on the slide and see what happens in the table. What happened now? Let's interpret these values (He moved around the class, observed what everybody did in front of their computers and helped them when they needed).

Student: When does the point A approach to the point B, it's $\Delta y/\Delta x$

Güven: Well, what would be the velocity of the car template at 2? What is your guess?

As can be seen from the excerpts above, Güven used technical questions which focus on the outcomes on the screen and promotes an understanding of instantaneous velocity. After getting the answer for instantaneous velocity, Güven went back to the geometrical meaning of it and asked his peers to find out where the chord approaches to. After getting “tangent” as the answer, he focused on the relationship between velocity and tangent with the following question:

Güven: Fatih, could you find a relationship between the velocity at the 2nd second and the tangent? I'm asking this question to everybody.

After that, he used the properties of the slide in Geogebra to get closer points by changing the increment from 1 to 0.1:

Güven: It becomes 3.99. OK. Is this enough for you?...Can we get closer values?

After that, Güven asked his peers to start Graphic Calculus software and to find out how the software calculate the rate of change ($\Delta y/\Delta x$) for smaller Δx. Some of the pre-service teachers mentioned that it approached to 4 when Δx is very small.

Güven: 0.0001 and this gives us 4. Can the slope be equal to 4?

Student: It can't be.

At this point he mentioned about the limitations of the software and that the slope of the chord can never be equal to 4 but the software makes an approximation. He then questioned the idea of limit and explained the mathematical definition of derivative at a point. To do that, Güven asked questions to promote an intuitive understanding of limit using the software and moved to the mathematical definition of derivative as the limit of rates of change.

DISCUSSION

Findings above indicated some strength and weaknesses of the pre-service teacher in integrating technology into his formative assessment practice. Güven was successful at asking technical questions which have two purposes. First of all, he focused on technical aspects and how the software perform certain tasks e.g. how to get smaller values of rate of change using the slide feature of Geogebra. Second, Güven used these questions to focus on the mathematical meaning behind what is observed on the computer screen e.g. the rate of change being 3.99 as the increment of the slide becomes 0.1, in other words, the idea of limit. At this point, Güven used a lot questions to promote an intuitive understanding of limit and its relationship with instantaneous velocity. In that sense, it can be claimed that his technical questions successfully focused on the interaction between technical and mathematical aspects. More importantly, interview data indicated his awareness of using the technical questions to promote an understanding of derivative.

Although Güven used extensive questioning during his lesson, he had some pedagogical weaknesses. For example, he did not give enough time to his peers to interpret the outcomes of the software and discover mathematical ideas. He performed some of the tasks by himself in a step by step manner which might yield to loosing the purpose of the task and dismiss the potential interplay between technical and mathematical aspects.

The study had some implications concerning the courses designed for pre-service mathematics teachers. As mentioned in the literature, assessment in general and assessment in CLE's in particular have not been a main focus of teacher training courses (Dywer, 1998; Heritage, 2007). This study aimed to help pre-service teachers equip with the required knowledge of formative assessment in CLE's. The workshops focused on how to use questions during a lesson in CLE's and pre-service teachers were encouraged to ask questions on what were performed by the software and their mathematical meanings to promote purposeful use of technology. The

workshop was effective in the sense that it provided a guideline for pre-service teachers to use questioning in CLE's.

This study has also implications at a theoretical level. Theoretical framework adapted from Pierce & Stacey (2004) provided a theoretical lens to analyse questioning practice for formative purposes in CLE's. For a further study, this framework could also be used to guide the programs for pre-service or in-service teachers in terms of how to use questioning in CLE's.

NOTES

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