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Influences of Technology Integrated Professional Development Course on Mathematics Teachers *

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Abstract: The aim of this study was to explore the degree to which a professional development (PD) program designed using GeoGebra influences a group of Turkish middle school teachers' beliefs in relation to mathematics and role of GeoGebra in mathematics education. In order to collect the required data, the PD course was established to provide six teachers with an opportunity to obtain practical experiences with and necessary knowledge about the use of GeoGebra in mathematics education. In this context, a multiple case study approach was utilized, in which mathematics teachers were observed and interviewed using a variety of procedures to expose qualitative data about their beliefs and the dynamics of their beliefs changes during the course. The main findings illustrated that teachers' beliefs were transformed to some extent in favour of the use of GeoGebra, as well as using constructivist ideas in their mathematics teaching and learning can be attained through the GeoGebra based PD course. In fact, the relationship amongst stated beliefs and intended teaching practice is complex and the social issues were very influential on teachers' pedagogical decisions. This research also introduces some suggestions for researchers who focus on professional development of mathematics teachers relative to their beliefs.

Keywords: *Professional development, Belief change, GeoGebra, Mathematics education.*

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Introduction

The reflections of advances in digital technologies including computers, graphic calculators, software and web-based applications have indicated its effects on all areas of education, in particular, in mathematics education (Goos & Bennison, 2008). It was important for many institutions to make vast investments in such innovations with the intention of incorporating digital computer tools into their educational curricula. As a result, countries felt the need to revise their educational policies and learning outcomes. With this aim, mathematics curriculum moved from a behavioural-focused system to an activity-based learning focus emphasising higher-order thinking skills and aiming to focus on conceptual understanding (Babadogan & Olkun, 2006). The basic target of this curriculum was to ensure effective participation of students in the learning process; and may be listed as offering opportunities for students to construct their own mathematical knowledge and gain mathematical thinking skills. Students move from being individuals waiting to receive ready information to being working individuals obtaining their own information. In this situation, teachers have more of a guiding role rather than just transferring information (Bulut, 2007). For the mathematics curriculum in Turkey it is also expected that public school teachers will use mathematical software (e.g. DGS and CAS) in their teaching.

Within the scope of the reform movement and efforts, the role of the teacher gained importance in the process of using innovative teaching methods (Wilson & Cooney, 2002). Teachers have a key role in the educational process. As a result, research about the constructs (attitudes, beliefs and knowledge) they have (Ball, 1988; Boz, 2008; Sanchez, 2011; Swan & Swain, 2010) and studies investigating the relationship between these constructs and applications in class have gained importance in recent years (Cross, 2009; Thompson, 1992; Ucar & Demirsoy, 2010; Zakaria & Maat, 2012). These constructs form important bonds between the leaning of teachers, applications in class and professional development. One of the noteworthy cases of beliefs has a clear effect on the role of teachers in the educational process (Nespor, 1987). Beliefs about mathematics continuously gain importance due to their key role in mathematics instruction have attracted the attention of researchers in the field of mathematics education (Aguirre & Speer, 2000;

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Beswick, 2005; Kul, 2012; Phillip, 2007; Stipek et al., 2001; Swan & Swain, 2010). It can be said that studying mathematics teachers' beliefs about subject matter that reflect their priorities for teaching practice in mathematics and is a significant part of understanding their actions in their classroom. According to Handal and Herrington (2003), effective reforms in education may change slowly or rapidly linked to the nature of common beliefs held by teachers. This is because teachers generally behave according to their own beliefs while creating learning environments. Beliefs are shaped by experiences lived by teachers in the past. In fact, teachers' beliefs are shaped by personal experiences in previous student processes and later by experiences obtained during teacher education in university (Philipp, 2007).

In the relevant literature in spite of teachers' participation in innovative reform movements, it was determined that innovative approaches were not reflected in teaching (Andrews & Hatch, 1999; Liljedahl, Rosken & Rolka, 2006). Despite rapid growth in technology resources, global movements to integrate new ideas into teaching and learning processes are relatively slow and more limited than expected (Ruthven, 2008). There are a number of significant factors that affect integration process into classrooms. One of the key factors behind this is teachers' beliefs and conceptions (Ertmer, 2005; Lavicza, 2010; Sadaf, Newby & Ertmer, 2012). In addition, teachers' beliefs might be explored predominantly for the understanding of the interactions between their beliefs and technology integration (Deng et al., 2014). Before applying changes made to mathematics education, teachers must be aware of the underlying benefits of these interventions and need to believe in them at the same time. Teachers having beliefs that will aid in realizing innovative teaching play an important role in reaching these targets (Handal & Herrington, 2003). However, change was imposed using a top-down model that was not concerned with teaching practice and the beliefs of teachers. In the absence of professional development, teachers are struggling to teach the curriculum effectively making use of new innovations. The implementation of innovative approaches in mathematics classrooms is reliant on a significant shift in teaching practices and a similar significant shift in teachers' beliefs about the nature of mathematics, its teaching and learning (Ernest, 1989). It is rather difficult to change teachers' beliefs (Pajares, 1992), however; it might be possible that changing beliefs through involvement with professional development course, from a constructivist perspective would be feasible (Guskey, 2002). This research puts forward the argument that teachers need to promote, through adoption, an approach based on the constructivist perspective utilizing technology in practice. This study will contribute to understanding the opinions of teachers related to teaching approaches and the productivity of professional development program.

Teachers' Beliefs

Studies investigating beliefs in the field of mathematics education have been conducted on different respondents (students, pre-service teachers and teachers) with different approaches or belief types. Every teacher has certain beliefs about students' learning, the syllabus, textbooks and self-efficacy and these beliefs determine priorities in mathematics teaching. Similarly, teachers' beliefs affect the approaches they value in mathematics teaching, the way these approaches are applied in class (Cross, 2009; Zakaria & Maat, 2012) and indirectly the students' beliefs about mathematics. In summary, in spite of many factors affecting how a teacher teaches, Speer (2005) showed a correlation between the teacher's mathematical beliefs and teaching. In this research, mathematical beliefs encompass specific beliefs in the area related to the nature of mathematics, mathematics teaching and learning. In this context, mathematical beliefs are what individuals believe to be true about mathematics (Cross, 2009) that shape teaching practice. Mathematical beliefs have been investigated by grouping in various forms by different researchers (Askew et al., 1997; Chan & Elliot, 2004; De Corte et al., 2002; Ernest, 1989; Perry, Howard & Tracey, 1999; Skemp, 1976) and the whole of the basic understandings and assumptions of these groups are assessed as a model. These belief models will be beneficial to guide our study. Ernest (1989) separated beliefs about the nature of mathematics according to three models of *Instrumentalist*, *Platonist* and *Problem solving*. Teachers with instrumentalist beliefs perceive mathematics as a mass of unrelated rules and truths. Teachers with Platonist beliefs consider mathematics as all knowledge based on immobile but related structures and truths and accept mathematical knowledge as not being created but rather existing knowledge that are discovered. According to teachers in the problem-solving stage, mathematics is a dynamic, problem-based and knowledge-producing process and is perceived as a continuously expanding field. Askew et al. (1997) classified beliefs about the nature, teaching and learning of mathematics in three models as *transmission, discovery* and *connectionist*, while Perry, Howard and Terry (1999) dealt the mathematical beliefs in their classification as two dimensions of *transmission* and *child-centeredness*. The above models may follow a path from traditional to constructivist ideas. In these studies it is not very important that the same belief groups are occasionally stated with different names (Thompson, 1992). Additionally, when statements are investigated, it is noted that as the levels increase, the content of statements move from behaviourist beliefs to constructivist beliefs, and flow from instrumentalist beliefs to problem-based beliefs. As a result, teachers with traditional beliefs considered mathematics as a cluster of tools formed by non-related rules and skills, and see mathematics teaching as about gaining sufficiency in rules and skills. According to teachers with constructivist beliefs, mathematics is a continuously expanding area consisting of dynamic, problem-based and information-producing processes (Ernest, 1989). These teachers believe that effective mathematics education in class settings may allow students to understand concepts with the aid of materials. Similar to the literature (Sang et al., 2009; Muis & Foy, 2010), the present study classifies such beliefs following a variety of viewpoints suggesting that a set of traditional and constructivist beliefs can be discerned through the manner in which mathematics is taught.

The Rationale for using a Technological Artefact (GeoGebra) in a PD course

Computer technology should be considered as one of the main components of teaching practice (NCTM, 2000). In recognition of this a number of digital technologies, specifically designed for use by mathematics educators, have emerged (Becta, 2009). In particular, specially designed for mathematics education software such as GeoGebra empowers learners to discover, observe patterns, make a conjecture, visualize, organize data and move objects on the screen beyond the scope of traditional pen-and-paper (Preiner, 2008). GeoGebra has been seen as a pedagogic tool which may develop higher order thinking and might also provide learners with a new perspective and vision through the dragging tool (Dikovic, 2009). GeoGebra is open source software with the potential to have some important features such as providing social interaction among learners (Hohenwarter & Preiner, 2007). The reason for using GeoGebra-based mathematical activities in the program is that the participants had taken a responsibility for their learning and this enabled them to reflect on and challenge their beliefs. The GeoGebra was used as a pedagogical tool to stimulate this challenging process and to encourage development of mathematical thinking through inquiry-based approach. For instance, the effect of all these advantages means that teachers learning with GeoGebra generally state positive opinions about this as revealed in a variety of research (Baltaci, Yildiz & Kosa, 2015; Kaleli Yilmaz, 2015; Kul, 2013; Mainali & Key, 2012; Tatar, 2013; Zakaria & Lee, 2012). Although digital technology becomes progressively prevalent in classrooms, little consideration has been paid to the need for continued and suitable professional development in such innovation. Teachers may appear to act as the primary mediator between technology and its integration in their teaching. Swan (2006) emphasized that any attempt to develop mathematical teaching practices of teachers must pay attention to the beliefs of mathematics teachers and to shifts in those beliefs. Therefore, the issue of teachers' perception of the use of computer technology in mathematical context with suitable pedagogical methods was the central focus of literature. From the viewpoint of the current research, exposing participants to new learning environment as learners through a professional development program is argued to be a constructive way to assist them in confronting and changing their beliefs. The aim of this study was to explore the degree to which PD program designed using GeoGebra influences a group of Turkish middle school teachers' beliefs in relation to mathematics and role of GeoGebra in mathematics education.

Methodology

Research Design

A multiple case study research design was used in this study to obtain in-depth information about teachers' mathematical beliefs and the dynamics of their changes in beliefs. A case study is a preferred research design of the current study because Merriam (1988) described this as an "examination of a specific phenomenon such as a program, an event, a person, a process, an institution, or a social group" (p.9). A case study is the research in depth by a researcher into a situation/event involving one or more individuals (Creswell, 2009). A case study is a preferred research design of the present study because the researcher's point of interest lies in the "how" question (Yin, 2009) which is reflected in the research question. As a result, in this research the multiple case study patterns were chosen to research in depth what teachers' mathematical beliefs were and how they changed. As a multiple-case study, the current study examines mathematical beliefs of six teachers within the PD course as they engage with activities and interact with their peers and the researcher. The phenomenon is teachers' interaction with the PD course and the context is the technology-based environment. Since it is important to contextualize the nature of social interactions within the PD course setting, a case study serves to explore teachers' beliefs and the way they change.

Participants and Procedure

The sample in this study for qualitative data is comprised of six middle school mathematics teachers. There were four teachers from the state school and two teachers from the private school. A total of six teachers' (5 males and 1 female) interactions were observed and interviewed before, during and after the PD course in a 22-hour workshop sessions. Before the PD course, the participants of the study have no knowledge about GeoGebra and its use in mathematics education. These teachers were selected on voluntary basis and were coded as T1, T2, T3, T4, T5 and T6. There are three main stages of GeoGebra-based PD program (see Figure 1).

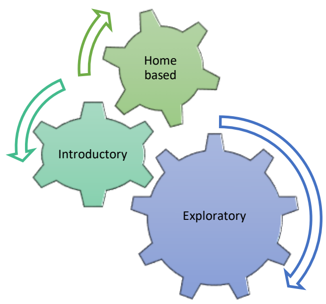

Figure 1. Stages in the PD course

In the initial stage of the program, some basic activities were provided for participants to become familiar with GeoGebra (lasting 4 hours). In the second stage, there were five worksheets involving pre-designed tasks regarding mathematics topics embodied in textbooks and GeoGebra website. The aim of these worksheets was to insert teachers into a practical setting, whereby they could explore and conjecture about tasks (lasting 16 hours). Individual and small group exploration, discussions among teachers was encouraged during this stage so as to share their notions about mathematical understanding. In the final stage, teachers were provided some opportunity to work on investigational mathematical tasks in their home, independently, in order to gain practical experiences and evaluate knowledge about GeoGebra. One of the aims of the PD course was to encourage cooperation and exploration of mathematical tasks when participants are working together with their peers in a group. The researcher's role in the PD course period was that of facilitator; this meant prioritizing the participants' freedom to articulate, explore and investigate mathematical concepts.

Data Generation Methods and Analysis

Three semi-structured interviews and participant observation were used for qualitative data to collect the required data from six middle school mathematics and to look at the dynamics of their beliefs change prior to, during and following their participation in the GeoGebra-based PD course. The interviews had five main foci 1) teachers' beliefs about the subject matter, 2) what it means to do mathematics, the purpose of teaching mathematics, how a student learns mathematics, 3) participants' experience about technology use in educational context, 4) the teacher's general impression about and reflections on the PD course activities, and (5) changes in the teacher's beliefs and their professional development. I took also some field notes about my observation of participants' discussion and interactions during the workshop sessions. Due to the nature of the study, data analysis was completed in accordance with the qualitative research paradigm. With this aim, data in the research were assessed with content analysis, because content analysis may be used in assessing interviews obtained through media (Cohen, Manion & Morrison, 2007). To check inter-coder reliability, the codes in some portions of the reduced data were cross-checked by the second coder with an educational research background to ensure consistency. The results of the coding and categorization of the second coder and that of the researcher largely matched one another. For different codes, the researchers met and consensus was reached. Concerning the identification of broader themes, after the process of coding and categorizing the data was completed, broader themes were tracked according to the research questions of the study. In this way, an attempt was made to ensure the reliability of the research. To increase the validity of the research, different data collection tools were used. Thus, more data variety was ensured in an attempt to achieve the aim of the research in detail. The constant comparison method was also used so as to ascertain themes relevant to participants.

Findings

Teachers' Initial Beliefs about Mathematics

This section explores the teachers' accounts related to their mathematical beliefs and the extent to which they were common to participants or were different from one another. Before entering the PD course, the teachers were interviewed to articulate their beliefs on the nature of mathematics and its teaching and learning. The course participants initially have multiple beliefs. As we have seen in discussing whether or not mathematics is created or discovered, there are some differences between participants' beliefs about mathematics. Here are examples:

T1: The first thing which comes to my mind is that mathematics is a collection of rules based on numbers...I think that mathematics consists of a combination of axioms and theorems.

T2: Mathematics is an interpretation, an alternative way of thinking; to be able to look at both sides of the coin, a process. In general it is a journey from the unknown to the known.

T3: Mathematics is a discovery. It even exists in nature. Human beings discover things, so they exist but we are unaware. The golden ratio of mathematics appears everywhere... The person who made this system is God who created us....

T5: I am 100 per cent sure it is a creation. People produce it as they need.... I think whole mathematical knowledge has been created.

T1 appeared to ruminate that mathematics is seen as a subject which essentially involves a static unified body of mathematical knowledge, involving a fixed set of procedures and formulas for computing algebraic expressions to determine correct answers. T2 characterized mathematics as pure logical thinking and as a medium for training the mind with its logic. Thus, in his belief, mathematics is a kind of activity for development of logical thinking. T5 held the belief that mathematical knowledge and theorems were invented by the minds of mathematicians and are continuously expanding its content. The PD course participants believed mathematics as essentially synonymous with the school subject. T3's beliefs appear to be partly traditional, in that they believe that mathematics has been created by God and is therefore 'absolute', but also believe that mathematics is discovered by human beings.

At the outset of the PD course, I asked the teachers for their opinions about the importance of mathematics and the main reasons for teaching and learning mathematics. For examples:

T1: It would enable them to better plan and spend their money. Maths can help people to develop their analytical side…

T3: I don't want my students to have the same kind of negative experiences that I had.

T4: My students' success must be high in exams; therefore, my goal is to attempt prepare every student to become successful in national exam.

T3 believed that the purpose of teaching and learning was about helping students to appreciate and enjoy mathematics. That is, he is interested in making mathematics enjoyable for his students and this is one of the motivating reasons for carrying out hands-on activities in the classroom. These ideas reflect typical constructivist beliefs about the primary aim of teaching and learning. The rest of the course teachers (e.g. T4) generally perceived mathematics to be positioned totally within an exam based education system. Thus, their purposes of teaching mathematics were concentrated on achievement. It is a view shared by the participants who typically made great efforts by teaching students to learn facts and to acquire the ability to manipulate numbers and solve algebraic equations. In brief, when participants' beliefs in the importance of mathematics is considered, it is believed that mathematics enables students developing their mental and social sides (e.g.T1). It is also believed that mathematics is seen as a gatekeeper and/or as a highly important subject to get success in school and public exams for their future education and employment.

The Main Reasons for Teaching and Learning of Mathematics

Key pedagogical views, perceptions and beliefs about teaching and learning of mathematics emerged from participants' responses to the first interview. The course participants held the belief that the school mathematics has covered many topics to learn and procedures to be followed, and the teacher would ensure that pupils master knowledge of these areas and know how and when to use the rules. These descriptions reflect how the teachers thought pupils learn not through active participation but through passive receipt in this process. The shared style to teaching mathematics by most of the PD course participants appeared to be whole-class lecturing. This belief is compatible with a traditional belief of learning and teaching where the learner is passive and the teacher's role is knowledge provider. Here is the example:

T6: The new curriculum encourages us to design teaching based on using group work, collaboration might help students to become more independent. The implementation of these ideas in the current classroom is not possible for various factors such as crowded classrooms, examinations and time.

T4: The new one is more interactive but gives us less time to prepare for the exams. That's why the students do not succeed in their exams. I mean it is a good thing not to memorize; but there is a limited time.

These comments suggested that the current mathematics curriculum tends to limit the teachers' opportunity to take full advantage of it. It is intense and there is not enough time to teach the whole curriculum in one year; therefore it is tempting for teachers to load students' heads with ready-made mathematical information that they are expected to remember and use in the exam, in order to save time. In contrast, T2 held the belief that students learn mathematics best by "doing and living" with help and guidance of a teacher, but they have no explicit ideas with reference to how this could or should be done. This belief is compatible with a constructivist view of learning and teaching where the learner is active and the teacher's role is facilitator. However, external factors became shared concerns of the course participants which may have an impact on their decision. In spite of a common feeling of disappointment with rote learning and practice, the participants seemed to have minimal knowledge of how to enact alternative pedagogical approaches. Furthermore, they had not explicitly articulated a clear aim for mathematics pedagogy. This study suggests that many of participants held teachers' beliefs about teaching and learning (e.g. T6) priori to their participation to the PD course were primarily traditional in nature. The remaining participants (e.g. T2) were found to hold combined constructivist and traditional pedagogical beliefs.

Shifts in the Participants' Mathematical Beliefs

In the short period of the PD course, rich mathematical discussion and engagements with self-directed and exploratory mathematical activities provided an opportunity to develop participants' professional experiences which encompasses both a new way of thinking of mathematics itself and their professional development. This was particularly true of the participants working in small groups with GeoGebra which created rich mathematical discussion environment between the peers. The teachers appeared to have felt confident in coping with the GeoGebra-based mathematical activities and experienced success rather than failure. However, as the course progressed, T2 articulated his opinions: "*new solutions can be invented by discussing with partner*" and "*you can come up with innovative ideas through interacting with GeoGebra activities*". Underlying his comments was a new way of thinking that could be linked to a broader belief of the nature of mathematics.

The course participants initially believed that mathematics consists of certain rules and procedures that students need to learn from a teacher, because they cannot invent or obtain mathematical knowledge on their own. However, their experience with the course helped them acquire a new sense of what it means to do mathematics. Their beliefs of mathematics became a product of interactions among people and objects. The participants' involvement with GeoGebra based activities helped them broaden their beliefs, from a somewhat fixed and absolutist-oriented standpoint to a more dynamic one. For example, T1 commented that "*Let alone the change in our minds, even children will be able to say that mathematics is not really something strange and to be afraid of...mathematics will make sense... mathematics is more than practising numbers... mathematics becomes more active through these activities*". These accounts of mathematics in some of their course reflections point to some change in their beliefs about mathematics in that mathematics was no longer static and fixed body of knowledge. This is a new way of thinking about mathematics that is entirely different from traditional beliefs about mathematics. And, this kind of shift appears to have been catalysed particularly by the dynamic and interactive nature of GeoGebra activities. It can be said that the PD course had an impact on a few participants' beliefs about the nature of mathematics to some extent in favour of the constructivist beliefs.

Regarding participants' beliefs about teaching and learning, more than half of the participants became more open to accept to ideas of constructivist perspective and reported some form of shift. Participants' engagements with open-ended mathematical activities in the PD course provided an opportunity to change their own previous experience with mathematics teaching and learning. The PD course also made it possible for the teachers to see mathematics learning and teaching from a different point of view, to think about an alternative teaching and learning. At the beginning of the PD course, T3 and T6 accepted the idea that memorisation and practice are important parts of mathematics teaching and learning. However, as the course sessions progressed, they began to accept the idea that learning mathematics is an active process, not passive one and the product of a student's effort to think something over in his/her own way and understand it. Their comments in the final interview suggested that this could be achieved with the help of teacher's guidance and encouragement which involve asking purposeful questions during teaching. They started to reject the idea of rote learning and support the constructivist perspective, believing that students need to discover and are able to do mathematics to learn the concepts best. Here is how participants assessed the PD course's influence on their beliefs about mathematics learning "the approach was used in this course totally eliminates "*rote learning*" and leads to a more "*understand the problem*" and "*way of looking at things*". T1 was already concerned with learning mathematics in a way that was connected with the essence of the course. He seemed to have found room to give his pupils a more active role in learning. This type of the PD course seemed to have supported most participants in gaining a new understanding of mathematical learning and teaching. Here is the evidence in T1's statement:

We always talk about student-centred education, active learning, students who can discover, make a conjecture, but where are they? How can this be done? What I saw in this course... this course helps me to see new teaching, and will offer a great support to establish my active class.

Another participant T5 looked at her role from combining two beliefs: a traditional and a constructivist. She appeared to believe that the teacher's role is to design active learning environment where student take on more responsibility for their own learning, and where students can use GeoGebra that might support them in mathematical knowledge construction. At the same time, the teachers were interested in monitoring the completion of activities without attempting to understand the nature of students' thinking. They also came to believe that good mathematics lesson progresses step-by-step in a planned sequence in the direction of the lesson aims. These participants form the most interesting group. Their pedagogical beliefs have indicated as both traditional and constructivist elements. This belief is supported by the following field notes:

T5: Teachers need to present the lesson and let their students explore. If students do not understand enough to follow the lecture, teachers will also need to use GeoGebra and combine traditional methods and group work with GeoGebra.

Participants' Reflections on GeoGebra Activities

The findings regarding to shifts in teachers' beliefs about the importance of GeoGebra use in the PD course were presented in this study. This involves shifts in the teachers' beliefs by comparing their beliefs at the initial stage of the PD course with those held at the end. Before the program began, T5 commented that "*If a teacher teaches well with using pen and paper, then she/he does not necessarily use GeoGebra in her/his teaching*". It can be inferred that she initially did not see GeoGebra as an essential component of teaching and appeared not to be aware of its potential.

Teachers' initial thinking about the importance of GeoGebra use in mathematics education was classified as two distinct views gathered from the first interview transcripts. Firstly, GeoGebra was seen as a motivator tool. Within this view, the GeoGebra would assist to stimulate students' motivation and interests towards mathematics learning. The second perspective was regarded GeoGebra as an image-maker which has the potential to turn into how geometry is introduced.

It is logical to anticipate that the teachers with an eight-week PD course based on use of GeoGebra promoted them to shift their personal feelings. The shifts were more influential in the some teachers who had lack of practical experience with GeoGebra. In particular, the GeoGebra-based program appeared to stimulate teachers' feelings of interest and enjoyment towards the use of GeoGebra in learning of mathematics, showing great eagerness for teaching mathematics along with it. The PD program would have an effect on the participant's beliefs about the importance of GeoGebra use. For instance, social interactions with colleagues during the GeoGebra-based investigational activities seemed to have facilitated them to re-consider their beliefs from seeing the GeoGebra as an additional tool for enriching his lesson to considering the GeoGebra as a pedagogical tool that can be employed to explore some concepts of mathematics and to enable learners to investigate things for their own sake. T1's verbal commentary is that "*Software like this is going to* *nurture students who are innovative, inventive and enthusiastic. Everything is in the learners' power and they can do whatever they want. The students are able to think outside the box*". For some participants, using mathematical software can play a significant role in students' learning and students might have opportunities to review and understand its potential. Here is the example, "*constructing an object in software, you have to use your imagination. When we are working on our tasks step by step; we are able to think in a mathematical way. Actually it requires deeper mathematical thinking so much in the process of construction*" [Field notes]. Another example, T3 changed from regarding as a means to calculate four operations to regarding it as image-maker which provide visual activities such as graphics, tables and diagrams so as to fill the gap in students' understanding from the teacher explanations on board. At the end of the PD program, one came to express the idea that using GeoGebra in lesson makes the teaching of the geometry easier, interesting and attractive. The findings of this study showed that while participants initially had multiple beliefs about the role of GeoGebra in mathematics, as the GeoGebra-based PD program progressed, they seemed more sensitized as to their beliefs, and also were more open to new ideas which may even contradict their beliefs. To sum up, two participants became aware of the potential for using GeoGebra as a didactical tool for development of the quality of mathematics education as a consequence of joining the program. After gaining experience with GeoGebra-based activities, the participants themselves developed new beliefs. However, for instance,

T2: However, there will be the problem. I cannot finish all the topics on time as a teacher. At the beginning, there may be difficulties when we use GeoGebra in an existing system. Later I think that we can overcome this difficulty...

T2's comment implied that the current mathematics curriculum tends to limit his opportunity to take full advantage of the potential of the GeoGebra. His comment also reflect the fact that they would probably always encounter the increasingly difficult task of finding time in teaching. Some expressed the intention to employ innovative ideas in their actual classroom, but were concerned that teaching using innovative practices would create some difficulties with planning and implementation. According to the participants, the educational context is not ready for, or flexible enough to allow teachers to spend their time developing GeoGebra-based activities, or to use group work in their class. Furthermore, time was a shared concern amongst the participants; they uniformly felt that the time required to implement innovative teaching strategies in the classroom was not available to them.

Discussion

The aim of this study was to explore the degree to which the PD program designed using GeoGebra influences a group of Turkish middle school teachers' beliefs in relation to mathematics and role of GeoGebra in mathematics education. This research have shown that teachers' beliefs were transformed to some extent in favour of the use of GeoGebra, as well as using constructivist ideas in their mathematics teaching can be attained through PD. This study, similar to other studies (Baltaci, Yildiz & Kosa, 2015; Horzum & Unlu, 2017; Kaleli Yilmaz, 2015; Mainali & Key, 2012; Tatar, 2013; Zakaria & Lee, 2012), showed that participants developed positive beliefs towards GeoGebra after a PD program based on GeoGebra for teachers. This experience arise due to novelty of GeoGebra that helped to activate participants' interest-excitement. However, they believed there was some obstacles such as time and national exams to bringing the application used in the course into the class environment and stated they had difficulty in being good GeoGebra users after education of this length. Teachers initially considered mathematics as a tool cluster formed by non-related rules and skills and saw mathematics teaching as gaining sufficiency in rules and skills (Ernest, 1989). These types of belief have been shown to be common in school systems. As a result of analysing data, the majority of the participants were initially found to hold multiple and/or mixed beliefs to varying degrees, a finding that mirrored that of Beswick (2005) and Askew et al., (1997). According to Ernest (1989) teachers have different types of mathematical beliefs and these beliefs may be harmonious or contradictory because they may be located in different areas of belief systems. According to Green (1971) as belief systems are not holistic logical systems, we may have incompliant or contradictory beliefs. This characteristics is related to beliefs being held in small bundles with no communication between them in the human mind.

Most of the studies categorized teachers' belief systems into theoretical constructs (Ernest, 1989; Perry et., 1999; Skemp, 1976). However, this study suggested that dividing teachers' beliefs according to these models did not offer a full picture of the situation. The study, in fact, revealed, that the complexity of teachers' beliefs does not fall neatly into the distinct categories suggested in other studies, in part due to the impact of social and cultural factors. For example, participants' core beliefs were considered as a potential barrier to willingness to alter their traditional beliefs. One implication of this is the possibility that teachers' beliefs cannot be analysed adequately in isolation from their context. Participants who held religious beliefs about mathematics still planned to integrate constructivist ideas into their teaching practice. Thus, this study suggests the relationship between participants' beliefs about mathematics and their intended teaching practices are complex, as the relationship between teachers' beliefs about teaching and learning and their beliefs about mathematics are not as straightforward as previous studies may have suggested. The findings of the present study were consistent with Pajares (1992) showed that teachers' beliefs included complex and messy constructs. Beliefs were inclined to grow incrementally and cultural elements were important in facilitating their development (McLeod, 1992). This finding is also consistent with Liljedahl, Rosken & Rolka (2006) and inconsistent with Cross (2009) and Chapman (2002), who suggested that beliefs are directly reflected in practice.

Moreover, participants in this study did not have clear ideas about pedagogy or their philosophical position relative to mathematics. In fact, the teachers were inclined to teach using the methods with which they were familiar and felt confident using; these naturally involved focusing on the more formal aspects of mathematics. It could be argued that educational contexts promote and support the development of traditional beliefs about teaching, because of their conservative nature (Handal, 2003). These beliefs typically emerge when a reform effort is fairly new and teachers are attempting to assimilate new teaching models with more conventional beliefs about the teaching and learning of mathematics (Stipek et al., 2001). This study shows that social teaching norms are the principal factors impeding the implementation of teaching practices (Bolden & Newton, 2008). The factor influencing Turkish teachers' decisions about teaching is the demands placed on them by the centralised educational system. Without the constraints of educational contexts, the PD course enabled the participants to challenge their fixed beliefs about mathematics teaching and learning. Many of the participants expressed their dissatisfaction with the emphasis on rote learning and practice in their classrooms, but had minimal knowledge of how to enact alternative pedagogical approaches. In other words, this course provided an opportunity to broaden and enrich Turkish primary teachers' beliefs about mathematics teaching and learning to align them more with the PD course approaches. This may suggest that teachers' reflections on their experiences with mathematics within the PD course could be seen as an effective way to change teachers' beliefs due to novelty experience.

As the participants learned about new ways in which to do mathematics, by utilising the scope of GeoGebra as a dynamic and interactive system, their belief systems shifted due to novelty experience. Placing emphasis on the value of peer collaboration, social interaction and ideas sharing to prompt teachers to attempt to use new tools and approaches. The integration of GeoGebra-based investigational tasks in the non-structured environment appeared to provide an opportunity for more purposeful teaching and learning experiences. The research illustrated that teachers' experience with mathematical activities within the course had instant and modifying influence on the beliefs. This finding is consistent with Liljedahl (2005). In terms of the research itself this was a key goal; however, what emerged as an extra finding, was that both the initial beliefs and the process of addressing and changing those beliefs were considerably more complex than had been originally assumed.

Conclusion

This study also contributes to the limited body of research on teachers' beliefs and professional development of primary mathematics teachers in reference to a GeoGebra integrated learning environment. One of the implications of this is that the researcher provided a tool, in the form of teachers' experiences within a GeoGebra-based PD course environment, with which to examine the nature and development of teachers' beliefs about mathematics, its teaching and learning. This study provided insight into Turkish mathematics teachers' beliefs about integrating technology into their current teaching, and information on which future research can draw to examine the effectiveness of GeoGebra in the mathematics classroom to assist students' learning. It is supposed that when teachers observe positive results in their students as a consequence of their actions, their levels of personal satisfaction as an intrinsic motivation in the workplace, will improve, assisting them towards greater professional success (Guskey, 2002).

This study does not clarify the relationship between changing beliefs and practices, since there was no follow-up to classroom observations. One cannot determine whether or not the participants were able to reflect on their new beliefs and effect changes to their teaching practice. In fact, some valuable ideas about teaching as related to mathematics were found through analysis of the participants' reflections on the PD course. It is evident that teachers need to be provided with more on-going support and interventions to embrace in depth and long-term changes in their practice. Given the short period of time in which the data collection process was conducted, teachers would be invited to reflect further on the beliefs they hold so as to enact them in their classrooms. This suggested that before attempting to comprehend the complexity of the nature of teachers' beliefs, it is essential to adopt a social and cultural perspective. Therefore, further research is required in order to capture the complexity involved in the cultural dimensions that influence mathematics teaching.

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