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An Exploration of Middle School Mathematics Teachers' Beliefs and Goals Regarding a Dynamic Tool in Mathematics Lessons: Case of GeoGebra

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Abstract: Currently, teaching with technology has become crucial. This case study investigated the beliefs and goals of four middle school mathematics teachers regarding a dynamic mathematics software: GeoGebra. The participants of the study were four mathematics teachers working in public middle schools in Turkey. The data was collected through semi-structured interviews, lesson observations and perceived technology, pedagogy and content knowledge surveys. Data analysis revealed a consensus on GeoGebra's usefulness in teaching units that link geometry and algebra. Most of the participants integrated GeoGebra to provide students with an explorative environment in which students were supported with feedback. Teachers' goals of using the software were found to be providing visual representations, facilitating students' learning, increasing students' engagement, as well as decreasing their workload and saving time. Moreover, teachers listed several challenges such as classroom management and lesson planning. Despite the challenges they faced, teachers were willing to integrate the software into their lessons. Therefore, complementary workshops were seemed to be necessary to overcome these challenges. These workshops might aim at providing the necessary 21st-century competencies for mathematics teachers to integrate the software into their lessons effectively.

Keywords: *Dynamic Tools; Case Study; GeoGebra; Mathematics Teachers; Middle School.*

Introduction

Teaching mathematics with technology is an important issue in the 21st century. While there are some opponents such as Batubara (2021) who says students might not be ready for learning through and with the help of technology and Mehanovic (2011) who lists a number of challenges of using technology in maths, a good number of researchers report the benefits of technology integration for mathematics teachers and their students. Some of these benefits were found to be providing immediate feedback (Benning, 2021; Kim & Reeves, 2007), increasing engagement (Mwingirwa & Miheso-O'Connor, 2016), facilitating students' learning and enhancing their understanding (Bu et al., 2011; Celen, 2020), and saving time for teachers to do extra work in the classroom (Hohenwarter et al., 2008; Suryani & Rofiki, 2020). Furthermore, information and communication technologies (ICT) provide teachers and students with easy access to knowledge and connections with their networks all around the world.

One of the most ambitious projects related to the effective integration of technology into middle school classrooms is Turkey's Movement to Enhance Opportunities and Improve Technology Project (2010). It aimed at enhancing software and hardware infrastructure, organising events for in-service teachers to discuss benefits and disadvantages of new technologies, providing e-sources for teachers of levels from primary to high school and giving training seminars to teachers on information and communication technologies. To achieve these goals, the latest technology of the time was provided to more than forty thousand students (out of eight million) and almost six hundred thousand classrooms.

After providing the necessary equipment, the next step of the project focused on some suggestions on how to use these. Accordingly, some dynamic software packages, including Cabri, GeoGebra and Microsoft Mathematics Software, were recommended to mathematics teachers for integrating into their middle school mathematics lessons. Being one of these dynamic software packages, GeoGebra was an easy-to-use, free, multi-platform and open-source software. Hence, it was not surprising that many teachers chose GeoGebra from the given options to use in their lessons (Icel, 2011; Karaarslan et al., 2013).

Studies on GeoGebra

GeoGebra, namely, is a combination of GEOmetry and alGEBRA. GeoGebra developers' team (2021) defines GeoGebra as "a dynamic mathematics software for teaching and learning". "Powerful, free, online graphing calculator and interactive geometry" terms were added to its description with the recent update. Researchers (Saralar et al., 2018; M. Bulut & Bulut, 2011; Edwards & Jones, 2006) have reported that GeoGebra acts as a bridge between geometry and algebra. They consider the tool as a useful one because of its data transformation with the help of different interfaces such as graphical and algebraic views. The tool is open source and does not require any licence to use, and its website has materials which are ready to use for teaching purposes. Some researchers (e.g., Grandgenett, 2007) argue that it is likely to find teaching materials on almost all topics of mathematics at all levels on the official GeoGebra website.

Studies on the effects of GeoGebra on middle school students' mathematics learning mostly reports positive results. For instance, Preiner (2008) found that lessons with GeoGebra facilitated students' learning by allowing students to explore properties of geometrical objects simply dragging them with a mouse and giving them an opportunity for more realistic mathematics lessons. Similarly, Healy and Hoyles (2011) and Ruthven (2005) reported that students got most of the expected learning outcomes by investigating and visualising mathematical concepts and by making logical deductions through GeoGebra. Specifically for the Turkish context, Dikkartin-Övez (2018) and Tezer (2018) reported, with 62 and 78 Turkish students, respectively, that GeoGebra-based lessons created a significant difference in students' maths achievement. More recently, Birgin and Uzun-Yazici (2021) reported that students who learnt mathematics through GeoGebra performed better than their peers who attended traditional lessons. However, studies found that the effects of GeoGebra are not entirely positive. For example, both Balgalmış et al. (2014) and Eryiğit (2010), who conducted studies in Turkey, indicated that the use of the tool requires some skills and competencies and gaining them took an essential time of a lesson where students can engage with problems or discussions on the topic. Hence, it seemed important to see whether this is the case in the researched context, Turkey. Moreover, researchers argued that GeoGebra-based lessons are time-consuming since they require some practice before actual mathematics learning (Preiner & Hohenwarter, 2007), and are indirect and experiential so challenging to relate with the mathematical content for both students and their teachers (Bates, 2005; Nur, 2010).

Theoretical Considerations

As this paper is an investigation of mathematics teachers' beliefs, it seems necessary to have a more in-depth discussion on teachers' beliefs regarding technology integration and their practices (especially about the dynamic mathematics tools).

“Individuals’ attitudes, beliefs, and emotions play a significant role in their interests and responses to mathematics in general, and their employment of mathematics in their individual lives” (Hannula et al., 2019b, p. 436). Given this, not surprisingly, teachers’ beliefs are inseparable parts of their teaching and are integral parts of their teaching practices (Nespor, 1987). Many researchers have reported a strong link between mathematics teachers’ beliefs and their teaching practices (Cross, 2009; Ernest, 1989; Stipek et al., 2001; Zakaria & Maat, 2012). For example, Cross’s (2009) study which examined maths teachers’ belief structures and their influence on instructional practices reported that there is a clear relationship between these constructs. More recent research keeps confirming these results which say there is a reciprocal relationship between teachers’ beliefs and their practices (Yang et al., 2020; Yurekli et al., 2020). Moreover, as seen in various studies, teachers’ beliefs -from their personal meaning to maths to their professional identities (Hannula et al., 2019a), from their self-efficacy (Zbiek & Hollebrands, 2008) to their values (Akyıldız et al., 2021; Clarkson et al., 2019)- affect their teaching practices, particularly whether and how they use technology in their lessons. Teachers are responsible for searching and examining teaching resources and tools, selecting the most appropriate technologies for their lessons, choosing effective ways to integrate those into their lessons, planning the content of these lessons, and designing learning environments for teaching. It should not be surprising to interpret that teachers are important decision-makers for their students’ learning with technology. Thus, the impact of their beliefs on determining classroom activities should not be ignored while investigating their practices with tools, and hence what teachers think about particular tools should be investigated together with their practices.

Teachers are required to have a fundamental knowledge of classroom technologies and to have the responsibility to gain necessary competencies for effectively integrating these into their teaching (Mishra & Koehler, 2006; Niess, 2008; Schmidt et al., 2009). Specifically, mathematics teachers need to know how to choose and use dynamic mathematics tools such as GeoGebra and Cabri to meet their students’ needs in the digital age. Moreover, learning how to use these tools might not be enough for effective technology integration. These teachers are also required to have good pedagogical skills to deliver effective lessons with these tools, hence techno-pedagogical skills are needed (Niess, 2005, 2006; Polly & Orrill, 2016). While they are expected to have all these techno-pedagogical skills to integrate digital tools into mathematics teaching, we do not know whether teachers think they have these capabilities yet. More precisely, it is crucial to learn teachers’ purposes while planning lessons with these tools and to investigate practices with them in real teaching environments.

Teachers’ beliefs regarding technology integration, especially about dynamic mathematics tools vary in studies conducted (see Musa et al., 2021; Wassie & Zergaw, 2019). In these studies, while some teachers believe that dynamic geometry tools help their teaching and students’ learning, some others believe that these tools are time-consuming and list a number of challenges. It is important to see whether the results of the Turkish mathematics teachers confirm the findings of wider literature. Given various classifications of technology integration (e.g., Bray & Tangney, 2017), in this context, it seems necessary to describe the term technology integration for use in this paper. In this study, it refers to the existence of a dynamic mathematics tool in classrooms. More specifically, it refers to Turkish teachers' use of GeoGebra mostly to "show and tell", and students' passive observation.

Summary and Research Questions

Labouring a big budget for technology integration and then suggesting some software packages for teachers to use were enough neither for effective technology use in classrooms nor for understanding whether the plans expectedly worked in classrooms. Thus, many studies evaluated the effectiveness of GeoGebra-based lessons focusing on the tool's possible effects on students' achievement in particular topics in mathematics (e.g., Alabdulaziz et al., 2021; Arbain & Shukor, 2015; Dikkartin-Övez, 2018; Tezer, 2018). On the other hand, there were much fewer studies about teachers' beliefs and their use of the tool in Turkey, and those which focused on teacher beliefs continuously reported a lack of evidence on how and for what purposes these teachers use GeoGebra in their particular contexts.

In the light of the reviewed literature, the following research questions emerged.

1-What are the middle school mathematics teachers' goals of and beliefs on using GeoGebra in Year-7 classes inTurkey?

a. For what purposes do they use GeoGebra in Year-7 classes?

b. What do they believe about the effectiveness of using GeoGebra?

Thus, the purpose of this study was to investigate middle school mathematics teachers' experiences with GeoGebra through investigating their goals of and beliefs on using the software.

Methods

This study followed a descriptive case study approach to explore teachers' beliefs and goals regarding dynamic mathematics software: GeoGebra. This was done to focus on a specific concept of teacher beliefs and goals regarding a particular software to reach an in-depth exploration of teachings beliefs and goals together with how they were using the software, as suggested by Yin (2017). In the present study, the case was GeoGebra-integration of four mathematics teachers. The researcher explored how and why these teachers were using GeoGebra in their middle school mathematics classrooms. Moreover, as Fraenkel et al (2015) state, the researcher attempted to describe experiences as viewed by particular individuals. For the present study, four individual mathematics teachers opened their lessons to the researcher to observe and they shared their experiences with GeoGebra in middle school contexts. To note, there was not any manipulation of the variables by the researcher to observe naturally occurring teaching settings.

Sampling and Participants

The study was conducted in four public middle schools in Turkey. These schools had the necessary technological infrastructure for integrating GeoGebra into lessons. This is, all of them had an interactive whiteboard, a computer in each classroom and a computer lab, and three of them had tablets distributed to all students. There were twenty to twenty-five students in each classroom. Year-7 students were selected as this is the middle year in middle school, hence students were neither fresher nor senior-grade students who are preparing for the high school exam.

The participants of the study were four middle school mathematics teachers from these schools: Denise, Hande, Jonathan and Melody. These teachers were the ones (out of all middle school teachers who uses GeoGebra in Turkey) who both have similar technologies available in their schools and had similar educational backgrounds regarding each other and the researcher, as follows: All of them attended in-service training sessions on effective integration of GeoGebra, had at least three-year classroom experiences and were teaching to the seventh graders. They completed teacher training high schools of their hometowns and, then, were graduated from the Middle School Mathematics Education programme of a public university in Ankara in 2013 and 2014. This is a four-year programme which offers mathematics, pedagogy, and technology courses. Both teachers and their students were familiar with mathematics lessons with GeoGebra before the study. All teachers volunteered to take part in the study. Names that appear in the article are pseudonyms.

Data Collection

The data of the study was collected through observations, semi-structured interviews and perceived technology, pedagogy and content knowledge surveys.

The participants were asked to choose a topic from the middle school mathematics curriculum to teach with GeoGebra. They were observed during their teaching in real classroom environments. Each lesson was forty minutes and teachers were free to spend as much time as they previously planned to teach the topic. They spent two to four lesson hours teaching the topics they chose.

Participants were interviewed face-to-face following the lesson observations. Each interview took approximately forty-five minutes and was audio-recorded. Interview questions focused upon research questions such as their motivation to use GeoGebra and whether they experienced any difficulties. Interviews had two phases. The first phase included questions directly related to teachers’ practices in the observed lessons whereas the second phase covered questions exploring teachers’ ideas on the software in their practices. Table 1 illustrates sample interview questions from both phases of the interviews.

Table 1

Sample Interview Questions from Interview Phases

Phase	Interview question
Phase 1	What did you want to achieve with GeoGebra today? What went well? Were there any (un)expected problems?
Phase 2	What do you think about the effectiveness of GeoGebra? Why is that? Can you give specific examples from your practice? What might be the difficulties of integrating GeoGebra, if any? Did you face any of these? How do you overcome these challenges? Can you give examples from your practice?

Finally, participants were asked to complete the Perceived Technology, Pedagogy and Content Knowledge (TPACK) Survey, prepared by Bulut (2012). The survey data were used to triangulate data collected through observations and interviews, and not intended to be used for generalisation. For example, in this six-point scale, one of the items was “I have difficulty solving technological problems in the classroom”. Teachers’ rates to this item on a 6-point Likert scale, transcribed interview data to corresponding interview question and their observed practices were triangulated, and the results were written accordingly.

Data Analysis

Qualitative methods analysed the data collected through interviews and observations. Steps of open coding were followed in order. These included labelling and sorting concepts, defining and developing categories, and identifying broader themes. Units of coding were sentences or phrases which were labelled on an Excel sheet. When coding, the researcher used Horzum and Ünlü’s (2017) priori codes, which emerged from the Turkish context, and added codes when necessary. Moreover, when compared, the codes were found to be similar to the studies conducted in other contexts, as in Mwingirwa and Miheso-O’Connor (2016) in Africa and McCulloch et al.’s (2018) study in the USA. Surveys were used as additional data and did not aim at making generalisations. Data gathered from the surveys supported the researcher in the description and identification of each case. TPACK survey scores of each participant were calculated by adding the answers of the participants to each of the items. Findings were thematically presented after the detailed explanation of each case. Table 2 summarises the themes of the study and notes the emerging themes and existing themes of Horzum and Ünlü (2017).

Table 2

Themes of the Study

Category	Theme	Status
Beliefs and goals	Providing visual representations	Existing
	Facilitating students' learning	Existing
	Increasing students' engagement	Emerging
	Decreasing teachers' workload	Emerging
Challenges	Classroom management	Existing
	Social context	Emerging
	Lesson planning	Existing
	Time management	Emerging

Researcher's Role

The researcher's role is important in qualitative research, as Merriam (1998) highlights. The researcher of this study is both a national education expert and a trained mathematics teacher who has a few years of teaching and volunteering experience in middle school classrooms both in Turkey and in England. She took courses on digital software integration to mathematics education, particularly on GeoGebra and Geometer's Sketchpad during her degrees.

It is important to note that the researcher was in continuous close contact with all participants during the data collection and the data analysis. This allowed her to get to know the participants better by giving her chances for informal discussions before and after the lesson observations. In addition to these, before the observations of GeoGebra-based lessons, the researcher spent some time in the classes for teachers and their students to be accustomed to her presence.

In this context, the researcher held both the observer and the interviewer role during the data collection. She followed the guidance of qualitative researchers such as Merriam (1998), Rubin and Rubin (1998) and Silverman (2005) while acting as an interviewer, and interviewed the participants accordingly. As an observer, she took observation notes during the study without any effect on the naturally occurring case.

Trustworthiness of the Study

All issues related to credibility (auditability), transferability (fittingness), dependability, confirmability, and goodness were considered throughout the study. First of all, there were other researchers during the observations, secondary observers, for the prolonged time in the classrooms as well as the researcher to decrease researcher bias. These were teacher-researchers who have master's degrees, working in these schools. Observation notes of both researchers, which were separately coded, were compared before going into further detail. Interrater agreement between the researcher and secondary observers was found to be Cohen's Kappa

= 0.84 (p<.001), suggesting a good agreement (Cohen, 1960). Throughout the data collection and the data analysis, the researcher tried to avoid expressing her position on using the software to minimise the researcher bias. Secondly, the researcher explained the process of the data collection, with a particular focus on the context, her role, and the analysis in detail, which is very common in case studies. To become more immersed with data, she made the transcriptions herself and read all the transcribed data and observation notes with plenty of time to come up with the themes. She also used the member-checking method, during which teachers were asked for further explanation of their answers so that they make the researcher ensure what they mean. The researcher was also aware that in this case study, there were four participants having similar educational backgrounds and experiences, and in-depth exploration of their beliefs and goals were reported. However, studies with teachers having different educational backgrounds, having different technologies available in their schools might give dissimilar results. Last but not least, the researcher tried her best to eliminate uncertainties and contradictions of results and attempted to ensure readers with her conclusion.

Results

This section starts with the table summarising the participants' backgrounds and TPACK scores so as to give a good overview of them (see Table 3). It then gives further details about the particular characteristics of each case before reporting the themes.

Particular Characteristics of the Cases

The case of Denise

Denise, the first participant, has a bachelor degree in Middle School Mathematics Education from an English-teaching university. She had taken elective courses related to two dynamic tools, GeoGebra and Geometer's Sketchpad, and passed both of these with AA which is the highest possible grade. She had working experience in both public and private schools for four years. As a part of the European Union Comenius Assistants Programme, she has taught in Italy as a Comenius teacher for an academic year. She summarised her experience there by stressing the importance of technology-integrated classrooms and said "In Italy, teachers are more conscious about using dynamic software (compared to teaching in Turkey), and they have more opportunities to use them. While working in Italy, it was very likely to utilize software like GeoGebra and to observe the advantages for students".

According to her answers on the perceived technology, pedagogy and content knowledge surveys, Denise was quite confident using digital technology in her maths lessons. She gave the highest point, which revealed the greatest agreement, to the item that says "I can easily create activities which require the use of dynamic technologies". She believes that there are positive effects of dynamic geometry in middle school lessons for both students and the teacher. She stated that she integrates GeoGebra into her lessons at least once a week making her the teacher who utilised the software the most among participants. Analytic Geometry, Circle and Circular Regions were the topics she listed when she was asked which units she liked to integrate GeoGebra. In her classroom implementation (observed by the researcher), she taught fractions with GeoGebra.

Table 3

Participants Background and TPACK Scores

Participant	Teaching experience		GeoGebra Use Frequency	TPACK score (/306)
	Year	Country		
Denise	4 years	Turkey, Italy	At least once a week	215 (20 items x 5 = 100 24 items x 4 = 96 5 items x 3 = 15 2 items x 2 = 4)
Hande	3 years	Turkey	Once a week	203 (15 items x 5 = 75 21 items x 4 = 84 14 items x 3 = 42 1 item x 2 = 2)
Jonathan	6 years	Turkey, The Czech Republic	Once a month	210 (15 items x 5 = 75 29 items x 4 = 116 5 items x 3 = 15 2 items x 2 = 4)
Melody	5 years	Turkey	Once-twice a month	241 (38 items x 5 = 190 12 items x 4 = 48 1 item x 3 = 3)

The case of Hande

Hande, as the second participant, graduated from a university where the Turkish language was the medium of instruction. She took two dynamic geometry courses during her bachelor degree, both of which were on uses of GeoGebra. These courses were in a computer lab where she had opportunities to create various GeoGebra activities in a group of three students. She observed four mathematics teachers from two public middle schools during her teacher training internship. She did not have tutoring experience other than her siblings and cousins. As a middle school mathematics teacher, she had been working in a public middle school for the last three years at the time of this study.

Her answers to the TPACK survey questions showed that Hande had a high level of theoretical and practical knowledge of using GeoGebra in middle school lessons although she had slightly less confidence in solving technical problems with the tool, technical problems which might appear during the classroom implementations. She noted that she is “actually using GeoGebra in just [teaching] geometry concepts”. Geometrical Shapes, Analytic Geometry and Circle and Circular Regions were three units she mentioned when she was asked which units she liked to integrate

GeoGebra. She was observed by the researcher while teaching Major and Minor Angles of Circles with GeoGebra.

The case of Jonathan

The third participant of the study was Jonathan. He got his bachelor degree from an English medium university. He had teaching experience in both public and private schools. He worked at a private exam centre as a mathematics teacher and prepared middle school students for the high school exam for three years. After that, he taught in the Czech Republic for an academic year. He summarized his maths teaching experience there by saying "The mathematics curriculum in the Czech Republic was very basic compared to the curriculum in Turkey. I think, the most difficult topic in the seventh grade was rational numbers in the Czech Republic, which is taught in the fifth grade in Turkey. I also realised that Czech teachers were not using dynamic software as much as we use in Turkey probably because they do not need it". After coming back to Turkey, he started working as a maths teacher in a public middle school and he has worked at the same school since then. He currently has six years of teaching experience in total.

The TPACK survey results revealed that Jonathan is confident using the dynamic software in different phases of the class, starting, middle, ending; however, he prefers to handle possible technological problems out of the classroom. Interview data supports the survey answer, in which he said "If I have a technical issue related to GeoGebra in class, I continue my lesson without using it. I try not to waste time. I can search about it and solve the problem at home". Jonathan mentioned Linearity and Circle and Circular Regions as his favourite topics for using GeoGebra while teaching to the seventh graders. He complained about his use of GeoGebra by saying "As a teacher who works in a little village school, I do not have enough chance to use GeoGebra very often". He said he "uses GeoGebra once a month". He taught rational numbers during the observed lessons with GeoGebra.

The case of Melody

Melody was the final participant in the current study. She completed her bachelor degree in a Turkish-teaching school where she took a classroom experience course and observed four mathematics teachers from two public middle schools for a year as a requirement of this course. She had tutoring experience since 2011. She believes that mathematics is an abstract science and says "Mathematical topics need to be visualised with the help of educational technology, and, therefore, I started learning about GeoGebra in 2012 with the help of my internship supervisors in the cooperating school of my university". She had been working in a middle school for the last three years at the time of the study.

Melody had the highest scores in perceived technology and pedagogy knowledge among four participants. This means that she considers herself as an experienced practitioner and a knowledgeable user of the software. Furthermore, she thinks that she "can solve technical problems related to GeoGebra quickly". She was also ready to help her colleagues whenever they ask for guidance on integrating GeoGebra into their middle school lessons. She said she integrates GeoGebra into her Year-7 lessons, once or twice a month with the belief that GeoGebra should mostly be used for teaching the topic rather than practising questions. Regarding this, she said that "Time is valuable and these students require to practise with different types of questions to be prepared for the high school examination". In her limited time with the tool, she teaches Linearity, Numbers and Proportional Reasoning. She was observed by the researcher while teaching orthogonal views of polycubes with GeoGebra.

Middle School Mathematics Teachers' Goals and Beliefs Regarding GeoGebra

There were four main themes in the category: middle school mathematics teachers' goals and beliefs regarding GeoGebra. These were providing visual representations (for teachers to show them to students), facilitating students' learning, increasing students' engagement, and decreasing workload.

Providing Visual Representations

The first of these appeared to be *providing visual representations*. This theme was about the visual representations GeoGebra provides, and how teachers perceive these representations. The types of visual representations on GeoGebra are algebraic, graphical, and geometric representations.

There was a consensus in stating that participants' primary purpose of using GeoGebra was providing visual representations. Denise, for example, stated that she believes that the visuals that GeoGebra provides help students learn maths more effectively, especially in middle school years. Denise's comment on this is as follows: "Because mathematics is an abstract science and because students at this age learn better with visual tools, I think GeoGebra can provide effective visuals for better student learning." Likewise, Hande put a big emphasis on the visualisation feature of the software especially when she teaches geometrical shapes. She was a teacher who mostly used GeoGebra herself to show visual representations she created in her lessons. Her reason for this in her words is that "GeoGebra gives a chance to 3D thinking. It is the tool to *show* all transformations, like iteration and rotation". Moreover, according to Jonathan, visual representations of GeoGebra are a visual approach to deep learning of mathematics for young children. Regarding this, he stated that "it is effective to use GeoGebra to visualise mathematical concepts and to teach them deeply – because direct teaching using pen and paper is only telling what to do. This is not enough for students, mostly because of their ages." In one of his observed lessons on teaching rational numbers, he created a rectangular shape on GeoGebra and divided this into ten and then a hundred equal pieces with the bar he previously created only in seconds. In the discussion after the lesson, he pointed out that if he would draw the shape on the interactive whiteboard with his hand, students might have some misunderstandings or misconceptions because he would not divide the shape into exactly equal ten or hundred parts without measuring. On the contrary, he reported that "with the help of GeoGebra, all of the students saw the equal parts and that prevented their possible misconceptions regarding this".

Facilitating Students' Learning

Facilitating students' learning was the second theme of the study. This theme was about teachers' comparison of students' grasp of mathematics topics with and without GeoGebra during their lessons.

All four participants expressed that GeoGebra is an effective tool that helps students grasp the mathematical relations in various topics, which are not quite easy for middle school students to learn such as Three-dimensional Shapes (Denise and Hande), Circle and Circular Regions (Denise, Hande and Jonathan), and Linearity (Jonathan and Melody). Despite very different examples from their experience, all teachers agreed with the idea that effective integration of this dynamic geometry software package facilitates their students' learning of the listed topics. For example, Hande, who taught major and minor angles of circles during the observed lessons, told in the interview that "Shapes and figures are not easy to teach to middle school students. However, GeoGebra makes these concepts easier to understand for them." Denise, who taught fractions in her lesson implementation, added that one of her main goals "to use GeoGebra was to help students' learning". Another example regarding this theme was from Jonathan who taught the definition of a circle using GeoGebra during his observed lessons. He stated that "Using paper and rope to show *a circle is a set of points which has an equal distance to a point, which is the centre* is not easy. I had to use this method last year because we did not have a smartboard. However, this year, after my representation with GeoGebra, it was really easy for students to discover the definition of a circle". He also specified that "The first step for drawing a circle on GeoGebra is to choose a point which will be defined as the centre of their circle". Thus, he told that "The steps of his construction are meant for his students, and thus GeoGebra facilitates students' learning". Figure 1 presents screenshots from the GeoGebra file which he opened and used in the observed lesson.

Figure 1

Screenshots of Jonathan's GeoGebra file

Increasing Students' Engagement

The third theme of the current study was *increasing students' engagement.* This theme as the name indicates was regarding teachers' perceptions of students' engagement with the mathematical content which teachers plan to teach.

Analyses of the interview and observation data showed that three teachers out of four mentioned one of their purposes to use GeoGebra as increasing students' engagement. To illustrate, Melody believes that students enjoy learning mathematics if she uses GeoGebra in her middle school lessons. She also said in the interview that students engage with the mathematical content through GeoGebra, so it is not only a motivation tool but also an instructional tool. Likewise, Denise expressed that she integrated GeoGebra into her classroom to engage students with the mathematical content. She stated that her aim while teaching Fractions with GeoGebra in an earlier lesson was to "make students' learning as permanent as possible by engaging them with the content through the representations GeoGebra provides".

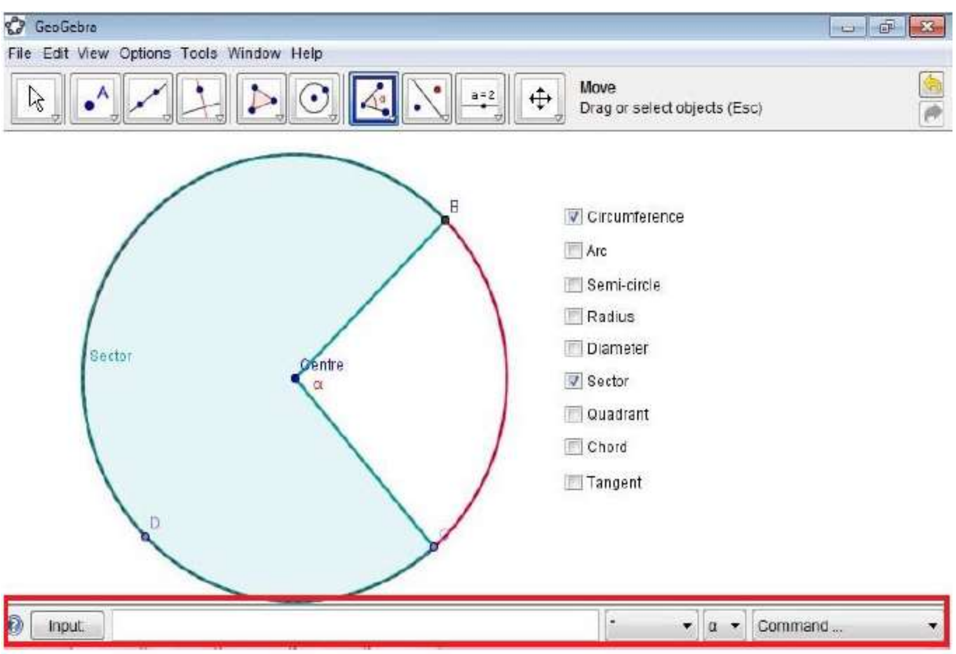
Decreasing Workload

The final theme in the goals and beliefs category was *decreasing workload.* The workload, in this context, includes teachers' responsibilities in and out of the classroom.

Half of the teachers stated in the interview that they believe integrating GeoGebra into their lessons provided an important reduction in their workload. Denise gave examples to this by saying "no need to carry manipulatives to classrooms" and "no need to draw figures to smartboard during class". She said she prefers to prepare GeoGebra files at home or to download ready-to-use GeoGebra files from the official GeoGebra website during the lesson. Hande's interview supported her ideas. During her lesson observation, Hande was observed to download a ready-to-use GeoGebra file to teach major and minor angles of a circle. The file came with a big circle, terms to choose next to the circle and an input bar (Figure 2). She asked various questions using the same circle. She did not need to draw or construct circles on the smartboard for her questions. She changed angles to prepare another question simply by dragging the rays or modifying the value of angle α in the input bar, marked in red in Figure 2. She said GeoGebra "facilitated and speeded up [her] drawing".

Figure 2

A screenshot of Hande's GeoGebra File



Middle School Mathematics Teachers’ Challenges While Integrating GeoGebra

The results showed that teachers’ general experience with GeoGebra was quite positive despite the challenges they faced. The most common challenges were found to be classroom management, social context, lesson planning and time management.

Classroom Management

The first of these is *classroom management*, reported by three fourths of the participants. This theme is related to the perceived actions mathematics teachers think they take to establish effective GeoGebra-based lessons to engage students with the topic whilst increasing their academic achievement.

In Denise’s case, for example, she said that students may lose their concentration and start talking while she is dealing with the technicalities of GeoGebra, thus “[she was] spending too much effort on taking students’ attention again”. She added that “sometimes, it is not possible. GeoGebra is a tool to enhance learning, using it is not the purpose of the lesson so after losing students’ attention, no need to carry on with it”. In the observed lesson, Denise faced technical problems and dealing with them whilst not showing enough attention to her students made Denise’s classroom difficult to manage. While Denise sees the reason for the difficulty in classroom management as technical requirements of the software and her abilities to handle these, Melody believes that the reason for this challenge is “students’ readiness to use GeoGebra as an instructional tool”. Similarly, “Students consider GeoGebra as a game and their behaviour sometimes become unbefitting of a student when I use GeoGebra”, says Melody.

Social Context

The social context was the second challenge while integrating GeoGebra. All participants discussed social context from different angles. Thus, this theme included the attitudes of both parents and school principals toward the use of technology, as well as achievement classes in schools. Achievement classes were the classes where students were chosen according to their academic performance, and this was extended to teachers’ lesson plans and schools’ short- and long-term educational goals. That is to say, maths teachers who work in these schools prepare separate lesson plans having problems with different levels of difficulty for high achieving and low achieving classes. The reason for preparing separate lesson plans is to meet both high achieving and low achieving students’ academic needs so that all students can better prepare for high school exam.

Jonathan was the only participant who stated that “[he] cannot give assignments to students on GeoGebra because neither school principals nor parents agree with the use of computers and tablets”. Unfortunately, most of the students do not have one as he is working in a public middle school in a small village, a school that had not received the latest technology as part of the FATIH Project at the time yet. Hande and Melody, who work in cities, discussed the achievement classes of their schools, and talked about the difficulty levels of questions they were asked by the principal to solve in these classes. They reported that all students were expected to practise various types of exam questions before the high school examination regardless of their achievement level. The thing which changes in this system is the difficulty of the problems they solved in the lessons. Because of all these reasons (parents’ and principals’ attitudes toward technology integration, and achievement classes), none of the participants integrated GeoGebra as much as they wanted to.

Lesson Planning

The third challenge was *lesson planning.* This theme focussed on mathematics teachers' plans of the lessons with GeoGebra rather than their actions during the lessons.

There was a consensus that planning a GeoGebra activity is difficult and requires a backup plan in case of a technological problem. For instance, Hande told that she has to consider electricity problems and added "I cannot solve problems related to electricity but certainly can prepare a Plan B. I print out the GeoGebra activity I prepared or I found. I back up all the questions I will ask during my class. In case the electricity goes off, immediately, I start writing [on the blackboard] using those papers". The problem related to the lesson planning was not only electricity. Indeed, three fourths of the teachers said that their schools got the smartboards in the last few years, and the Internet connection is still not available, so they had to carry their flash drives with them all the time. It is of note that Denise and Jonathan, working in villages, preferred to give further explanations about their schools' technology infrastructure and its limitations while talking about their planning. However, Melody and Hande, who work in schools in cities, mostly talked about their backup plans as the challenge during lesson planning with GeoGebra.

Time Management

Time management was the last challenge and mentioned by half of the participants. As the name indicates, this theme covered the issues related to time management, particularly, the in-class time devoted to teaching with GeoGebra.

Both Denise and Hande stated that it could be unnecessary and time-taking to integrate GeoGebra into high-achieving classes as most of the students in them perform better than their peers already, without GeoGebra. According to Hande, "[when she uses GeoGebra] it is likely to face problems with high-achieving students because they could be impatient while waiting for her to draw a shape on GeoGebra, and there is not always time to prepare or find extra activities for early-finishers to solve while waiting". Denise adds to that by talking about her lesson implementation with these words: "GeoGebra was helpful for some students who were middle- and low-achieving. On the other hand, it was time-consuming for successful students". She has observed during her lesson with GeoGebra that high achieving students finished the activity earlier and early-finishers disturbed other students who [according to her] needed to listen to [her] explanations.

Discussion and Conclusion

The motive for this study was to explore the beliefs and goals of middle school mathematics teachers concerning the integration of GeoGebra in Year 7. Qualitative analysis of the data revealed that mathematics teachers used GeoGebra for various purposes from providing visual representations to facilitating students' learning, from increasing students' engagement to decreasing their workload. Participating teachers also reported some challenges including classroom management, social context, lesson planning and time management.

Participants, overall, demonstrated a willingness to use GeoGebra despite all the challenges they face. Considering this, it might be important to highlight the fact that all of the participants continue to integrate GeoGebra into their lessons, believing its effectiveness. This finding might have resulted from them having medium and high levels of technology, pedagogy, and content knowledge. As explained, Balgalmış and colleagues (2014) found that teachers' knowledge and confidence levels are interrelated. Particularly for the current study, three of the participants (Denise, Jonathan, and Melody) were quite confident in integrating educational technologies. Melody had the highest TPACK score, and Denise and Jonathan had enough confidence in solving technical problems related to GeoGebra. Hande was the only participant who has a medium level of perceived TPACK. TPACK knowledge survey analysis showed that although she has enough theoretical and practical knowledge, she does not have enough confidence to solve any technical problem during her lesson implementations. This could be because of various reasons. She might think that trying to solve technological problems might increase her workload or that dealing with them could be time-consuming for her. She was the only participant who does not speak English and does not have international work experience, which may have affected her knowledge and self-esteem.

Although four teachers continue integrating GeoGebra into their lessons, it is worth discussing that teachers do not or cannot let students use GeoGebra on their own (e.g., in Jonathan's school parents and principal do not agree with it). The findings of the study with these four teachers found that GeoGebra is considered as a teaching tool for teachers to use instead of a learning tool for students to engage with as in Agyei and Benning (2015). This might be because classroom management was one of the biggest challenges stated by the teachers. Three of the teachers expressed that when they let students use the tool, they are afraid of losing control of the classroom. This could as well be because of many reasons. For example, the teachers were novices (in their first three to six years), and with practice, their confidence might increase (Saralar-Aras & Firat, 2021; Unal & Unal, 2012).

To conclude, all of the teachers in the present study believe that GeoGebra is an effective tool for teaching mathematics. They used the tool according to their students' needs and they did not use it when they felt it was unnecessary and time-consuming. Although the teachers stated many challenges, they seemed to enjoy using GeoGebra and were happy to talk about their plans with it.

Recommendations for Future Studies

First of all, the implementations with GeoGebra might not be the only way to achieve the same pattern of results. Studies on other educational tools such as Cabri and Geometer's SketchPad might be suggested to investigate whether the selection of the software creates a difference in terms of teachers' goals and beliefs. Secondly, the study might be extended to other grade levels rather than the seventh grade and might be replicated in an increased number of participants. Last but not least, longitudinal studies focussing on practices rather than beliefs might also be recommended. These studies might be conducted to investigate the link between teacher knowledge and their strategies to integrate GeoGebra. Such studies are highly recommended because they might have the potential to explain why teachers with high levels of perceived TPACK chose to continue integrating GeoGebra despite a number of difficulties they face.

Implications for Educational Practices

The findings of the study might provide researchers, programme developers, middle school teachers and policymakers with essential information related to the middle school teachers' purposes of use and beliefs regarding GeoGebra, and the difficulties when teachers use this tool in their seventh-grade classes. This study might not only help teachers to gain self-awareness of their beliefs and practices with the tool whilst discussing them during the interviews (Hohenwarter et al., 2008) but also provide them with a chance to teach with technology-based lesson plans. Related to this, participating teachers' teaching might be improved through the reflection process during the interviews on their practices. Moreover, teachers' GeoGebra-based lesson plans and backup plans to be used if GeoGebra fails to work might set good examples for other teachers.

It might be advised to programme developers to improve or update the content of existing pre-service and in-service training sessions so that they meet the needs of teachers and help them overcome the challenges they might have. For this reason, complementary GeoGebra activities could be added to existing training sessions to teach necessary technological and pedagogical skills (Preiner & Hohenwarter, 2007; Koehler & Mishra, 2009; Niess, 2006). In addition to these, follow-up workshops could be suggested to provide opportunities for teachers and prospective teachers to practice what they have learnt before using the tool in real classrooms. This might help them discover the potential of the software and the practical use of it and reach the expertise to guide students to achieve expected learning outcomes. The final point regarding the students' guidance is important as it was observed in most of the lessons that GeoGebra was a tool for teachers to use and the students to look at, passively; and other lessons were quite focused on teachers.

All in all, attitudes, beliefs, and emotions all play a part in people's interest in and responses to mathematics in general, as well as their use of mathematics in their daily lives (Hannula et al., 2019b). As a result, it is not unexpected that teachers' values are inextricably linked to their teaching and are vital to their methods (Nespor, 1987). Many studies have found a substantial correlation between math teachers' views and their teaching methods (Cross, 2009; Stipek et al., 2001; Zakaria & Maat, 2012). Teachers are in charge of finding and evaluating teaching resources and tools, selecting the most appropriate technologies for their lessons, determining the most effective ways to incorporate those technologies into their lessons, planning the content of these lessons, and creating teaching environments. It should come as no surprise that teachers have a significant role in their classes' learning with technology. Hence, the current study investigated mathematics teachers' beliefs and goals regarding the integration of GeoGebra into Year 7 classes.

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