

PRE-SERVICE ELEMENTARY MATHEMATICS TEACHERS' VIEWS ABOUT  
USING GRAPHING CALCULATORS IN ELEMENTARY SCHOOL ALGEBRA:  
THE CASE OF USING CLASSPAD

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ALGEBRA: THE CASE OF CLASSPAD**

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## **ABSTRACT**

### **PRE-SERVICE ELEMENTARY MATHEMATICS TEACHERS' VIEWS ABOUT USING GRAPHING CALCULATORS IN ELEMENTARY SCHOOL ALGEBRA: THE CASE OF USING CLASSPAD**

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Mathematics education could and should benefit from technology in order to improve teaching and learning, particularly in topics where visualizations and connections to other concepts are needed. Handheld technologies such as graphing calculators can provide students with visualization, confirmation and exploration of problems and concepts they are learning. Handheld graphing technologies have been taken place widely in elementary and secondary level mathematics courses and considered to be beneficial in various means in mathematics education. Mathematics teachers have a crucial role in the use of GCs in mathematics classrooms. Therefore, pre-service teachers' use of GCs and their views on the use of the tool in mathematics learning are considered to be valuable.

The purpose of this study was to investigate the difficulties pre-service elementary mathematics teachers face, and the benefits and constraints they emphasize while learning elementary school algebra through using the Casio Classpad after receiving an instruction with graphing calculators. The graphing calculator used in the present study is the Casio Classpad 330, which is an evolved

handheld device combining features of graphing calculators, dynamic geometry environment, computer algebra systems and more.

The following two research problems guided the study: What are the difficulties do pre-service elementary mathematics teachers face while using Classpad in learning elementary school algebra after receiving an instruction with graphing calculators? What benefits and constraints do pre-service elementary mathematics teachers emphasize while learning elementary school algebra through using Classpad after receiving an instruction with graphing calculators?

With the aim of investigating the views of a group of pre-service elementary mathematics teachers, qualitative research strategies were used. The data was collected and analyzed by means of a case study design. Classroom observations, a questionnaire, and focus group interviews were the main data sources of the existing study. The study was carried out with 21 pre-service elementary mathematics teachers. In the classroom studies elementary level algebra was taught to the participants with the use of Classpad as a main tool by giving one tool to each of the participants. Classroom observations ended in five weeks – 20 courses – including one week of a training period. After the classroom observations, participants filled out a questionnaire including five open-ended questions about the classroom studies. Finally, data collection procedure was ended with three focus group interviews. The data was analyzed with qualitative means by transcribing and analyzing the observation records, answers of the questionnaire, and records of the three interviews.

Results revealed that pre-service teachers' view Classpad in three categories; as a personal tool, as an educational tool, and the relationship between CP and motivation. They viewed CP as a personal tool that they were eager to use the tool in every level of mathematics from elementary to mastering degrees. As an educational tool, they preferred to use the tool as a teacher by giving some cautions that teachers and students should be careful with. Lastly, they considered that the tool has a positive effect on motivation when used appropriately. Pre-service elementary

mathematics teachers faced some difficulties in the beginning courses of the classroom studies which was their learning period of how to use CP and they overcome most of the difficulties at the end of the classroom studies. As the new elementary school level mathematics curriculum encourages the use of various technologies in teaching and learning of mathematics, the results of this study will have useful implications for mathematics teachers and curriculum developers.

Keywords: Graphing calculators, Casio Classpad, technology integrations, algebra, elementary mathematics education.

## ÖZ

### İLKÖĞRETİM MATEMATİK ÖĞRETMENLİĞİ ÖĞRETMEN ADAYLARININ İLKÖĞRETİM CEBİR ALANINDA GRAFİK HESAP MAKİNESİ KULLANIMI İLE İLGİLİ GÖRÜŞLERİ: CLASSPAD ÖRNEĞİ

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Öğretim ve öğrenimin gelişmesi için, özellikle görselleştirmeye ve diğer kavramlara bağlantı kurmaya ihtiyaç duyulan konularda matematik eğitimi teknolojiden faydalanmalıdır. Grafik hesap makineleri gibi elde taşınabilir teknolojiler, öğrencilere öğrenmekte oldukları problemler ve kavramlarda görsellik, onaylama ve keşfetme imkanlarını sağlayabilir. Elde taşınabilir grafik teknolojileri, ilköğretim ve ortaöğretim matematik derslerinde geniş olarak yer almaktadır ve matematik eğitiminde birçok yönden yararlı olarak görülmektedir. Matematik öğretmenleri, matematik derslerinde grafik hesap makinesi kullanımında önemli rol üstlenmektedirler. Bundan dolayı, öğretmen adaylarının grafik hesap makinesi kullanımı ve matematik öğrenimindeki kullanımı hakkındaki görüşleri önemli olarak görülmektedir.

Bu çalışmanın amacı, ilköğretim matematik öğretmenliği öğretmen adaylarının grafik hesap makinesi kullanımı ile ilgili eğitim aldıktan sonra Casio

Classpad kullanılan cebir öğrenim sürecinde karşılaştıkları zorlukları ve vurguladıkları faydaları ve sınırlılıkları incelemektir. Bu çalışmada, elde taşınabilen gelişmiş bir araç olan ve grafik hesap makinelerinin özelliklerini birleştiren Casio Classpad 330 grafik hesap makinesi kullanılmıştır.

Bu çalışmaya rehberlik eden iki araştırma sorusu şunlardır: Grafik hesap makineleri hakkında eğitim aldıktan sonra, ilköğretim matematik öğretmenliği öğretmen adayları Casio Classpad 330 kullanarak öğrendikleri ilköğretim cebir dersinde ne gibi zorluklarla karşılaşmıştır? Grafik hesap makineleri hakkında eğitim aldıktan sonra, ilköğretim matematik öğretmenliği öğretmen adaylarının Casio Classpad 330 kullanarak öğrendikleri ilköğretim cebir dersinde karşılaştıkları faydalar ve kısıtlamalar nelerdir?

İlköğretim matematik öğretmenliği öğretmen adaylarının görüşlerini almak amacıyla, nitel araştırma yöntemleri kullanılmıştır. Veriler toplandıktan sonra durum çalışması yapılarak analiz edilmiştir. Sınıf gözlemleri, anketler ve odak grup görüşmeleri çalışmanın verilerini oluşturmaktadır. Çalışmanın katılımcıları ilköğretim matematik öğretmenliği bölümünden 21 öğretmen adayıdır. Sınıf içi çalışmada öğretmen adaylarına ilköğretim düzeyinde cebir konuları, Casio Classpad 330 kullanılarak öğretilmiştir. Sınıf içi eğitimlere katılan her öğretmen adayına bir Casio Classpad 330 temin edilmiştir. Sınıf içi gözlemler bir haftası grafik hesap makineleri eğitimi olmak üzere 5 hafta ve 20 ders saatlik süreden oluşmaktadır. Sınıf içi gözlemlerden sonra katılımcılar, sınıf içi eğitimlerle ilgili beş açık uçlu sorudan oluşan bir anketi cevaplandırmıştır. Son olarak, veri toplama, üç odak grup görüşmesi yapılarak sona erdirilmiştir. Veriler kayıtların gözlenmesi ve yazıya aktarılması, anketlerden elde edilen sonuçlar ve odak grup görüşmelerinin incelenmesi ile analiz edilmiştir.

Öğretmen adaylarından elde edilen verilere göre araştırmanın sonuçları Classpad'i üç kategoride tanımlamaktadır: kişisel bir araç olarak CP, eğitsel bir araç olarak CP ve CP ile motivasyon arasındaki ilişki. Öğretmen adayları, grafik hesap makinelerinin ilköğretimden yüksek lisansa her seviyede kullanılabilecek kişisel bir



araç olarak, bazı eğitsel uyarılar doğrultusunda öğretmen olarak kullanabilecekleri eğitsel bir araç ve doğru kullanıldığında motivasyon üzerinde olumlu etki yaratan motive edici bir araç olarak tanımlamışlardır. İlköğretim matematik öğretmenliği öğretmen adayları sınıf içi eğitimlerinin başında Casio Classpad 330'un kullanımıyla ilgili bazı zorluklarla karşılaşmış; fakat eğitimlerin sonunda zorlukların hepsinin üstesinden gelmişlerdir. Farklı teknolojilerin kullanımını teşvik eden yeni ilköğretim matematik programı doğrultusunda, bu çalışmanın matematik öğretmenleri ve program geliştirme uzmanları için faydalı olacağı düşünülmektedir.

**Anahtar Kelimeler:** Grafik hesap makineleri, Casio Classpad 330, teknoloji entegrasyonu, cebir, ilköğretim matematik eğitimi.

**To my family and my dearest friend Deniz Gönenç Sümer**

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## **LIST OF ABBREVIATIONS**

GC	: Graphing Calculator
CP	: Classpad
CSE	: Computer Supported Education
NCTM	: The National Council of Teachers of Mathematics
METU	: Middle East Technical University
f	: Frequency

## **CHAPTER 1**

### **INTRODUCTION**

Handheld graphing technology has been a frequently used technological tool in mathematics education for the last three decades since the instructional tools such as calculators, GCs, information and communication technologies and educational computer programs have been developed (Aydın, 2005; Ersoy, 1997, 2001, 2005; Burrill et al., 2002; Kastberg & Leatham, 2005). When the use of GCs in the various world education systems is considered, in the USA (Keller & Hirsch, 1998; NCTM, 2000; Thompson & Senk, 2001), in Europe (Guin & Trouche, 1998; Hennessy, Fung, & Scanlon, 2001; Ruthven, 1990) especially in Britain and France, and in Australia (Boers & Jones, 1994; Forster & Mueller, 2001; Forster & Taylor, 2000; Mitchelmore & Cavanagh, 2000) they are being frequently used in undergraduate and pre-college mathematics education since that time.

There are various reasons why handheld graphing technologies have had a permanent place in mathematics education. One of the reasons is that, since GCs have been produced, they are getting cheaper, more useful, portable, convenient, practical, handy, manageable, available, and more functional (Doerr & Zangor, 2000; Kissane, 1995). Mitchelmore and Cavanagh (2000) confirmed this idea as follows:

“GCs were first developed in the mid 1980s and since that time have become steadily cheaper, user-friendlier, and more powerful” (p.254).

Furthermore, GCs are accepted and proved to be devices that provide opportunities in exploring, investigating and discovering mathematics (Hennessy et al., 2001; Özgün-Koca, 2009). Moreover, there is considerable number of studies which found evidence that technology use enhance students’ conceptual

understanding of mathematics (Burrill et al., 2002; Doerr & Zangor, 2000; Özgün-Koca, 2009). Yet, integrating technology in a traditional curriculum needs some steps to achieve in terms of the teachers' and students' use of GCs. Teachers and students pass through some stages of adapting GCs into mathematics and developing teaching skills and abilities, replacing traditional paper-pencil problem solving habits by GCs. Although the views of the students who are the users of the GCs are important, teachers' ideas are also worth considering as teachers have a crucial role in the use of GCs in mathematics education (Heller and Curtis, 2005; Kissane, 2002, 2003; Laumakis & Herman, 2008; NCTM, 2003).

GC use is very common in secondary and high school education in the United States (Doerr & Zangor, 2000) where the frequency of the usage differs between the states. In some of them GCs are used both in the classrooms and state assessments whereas in others GCs are used only in classrooms during teaching and learning process.

When compared to the United States, the implementation of the GC use in Turkish Mathematics Education Curriculum is perceived as difficult and unnecessary for both students and teachers (Ersoy, 2005). However, new Turkish Elementary and Secondary Mathematics Education Curriculums emphasize technology use more than the previous curriculum (MEB, 2007). For example, in elementary school curriculum, it is suggested to use calculators in calculations. In addition, it is mentioned that students can develop reasoning and creative thinking skills rather than spending their time in long calculations. The use of technological tools is among the aims of the new curriculum, especially in fields such as physics, chemistry, and mathematics. In the new mathematics curriculum, the importance and role given to technology can be recognized easily by looking at the mathematical activities at which technological tools such as calculators are used as the main tools (MEB, 2007). Among the technological tools, handheld GCs are rarely used in Turkey, only in some public schools that are chosen as pilot schools and in some private schools. The technological tools such as GCs can take their place in education with the collaboration of researchers, curriculum developers, teachers, and students for

implementation of GCs in pre-college level mathematical subjects (Burrill, et al., 2002; Ersoy, 2005). Although some curriculum developers and mathematics educators doubt that adapting GCs into mathematics curricula in some grades can cause problems, previous research shows that problems can be faced by educating teachers' and students' effective use of the GCs (Burrill et. al., 2002; Ersoy, 2003; Heller and Curtis, 2005; Hennessy et. al., 2001).

There is not much research in the area of implementing GCs into mathematics education regarding the mathematical subjects in Turkish Mathematics Education Curriculum is very rare (Ersoy, 1994; 2000) when compared to the educational researches in other countries such as the United States of America and England. As it is a new step and a different view for mathematics education in Turkey, teachers should be informed and trained, students' use of the GCs should be observed and the mathematics curriculum should be revised accordingly (Baki & Çelik, 2005). Obtaining the views of in-service teachers, pre-service teachers and students about the process, by examining the needs, complains and advantages they express will provide important data to improve the implementation of GCs in mathematics education.

As the basic learning of mathematics takes place in elementary, middle and secondary levels, the studies are generally around the elementary and secondary school students and teachers. There are many studies on learning the basic concepts in mathematics such as functions, algebra, and calculus with the use of a GC in pre-college level. Among the mathematical subjects, algebra is considered as one of the basic subjects to develop upper level mathematics such as calculus. Several studies show that students have difficulties in learning algebraic concepts. Hence, achievement in algebra is low in pre-college level (Dahland & Lingefjard; 1996; Forster & Mueller, 2001; Graham & Thomas, 2000; Huntley et. al., 2000). The fact of algebra being a problematic area in mathematics education, leads to create new teaching methods for the students to show better performance in algebra. In this point, the possible benefits of technology are worth to be considered. These benefits in terms of a GC can be listed as visualization, multiple representations,

transformation, and computation (Doerr & Zangor, 2000; Forster & Mueller, 2001; Hennessy et al., 2001; Özgün-Koca, 2009). In fact, identifying algebraic expressions with visual expressions such as relating equations with graphics and figures is specified in Turkish Elementary Mathematics Education Curriculum (MEB, 2007). Algebraic expressions and equations are suggested to be thought with using multiple representations approach in order to provide connection between symbols, graphs, value tables, and algebraic expressions. In addition, GCs are the suggested tools to be used in the teaching of algebra, as they include applications related with multiple representations approach (MEB, 2007).

It is evident that teachers' views on the use of handheld graphing technologies in teaching and learning mathematics influence their use of technology in mathematics classrooms (Brinkerhoff, 2006; Ersoy & Baki, 2004; Özgün-Koca, 2009; Thompson, 1992). In the previous studies it was found that views of pre-service and in-service teachers on the use of GCs in mathematics instruction differs according to their past experiences with technology. Teachers' views on the benefits of GCs develop according to their use of the tool. In other words, teachers who gain experience with a GC more, believe its effectiveness on learning and construction of mathematical concepts more (Mason, 2010). Teachers having little or no experience with technology develop negative views about the use of GCs in mathematics education (Johnson, 2008; Mason, 2010). Considering the gaps in the literature, more studies investigating the views of pre-service teachers are needed to enlighten the needs about, necessary developments in and benefits of the use of GCs in mathematics education. This study intended to enlighten the research area on GCs by investigating pre-service elementary mathematics teachers' use of a qualified handheld technological tool – Casio Classpad (CP) – in learning and teaching algebra.

### **1.1 Purpose of the Study**

A review of research studies and reports show the need for pre-service teachers to have the basic information on the use of handheld graphing technologies

(NCTM, 2000; Özgün-Koca, 2009; Ersoy & Baki, 2004). This can come true by providing them the knowledge and competent experience on the use of technology during their university education (Ersoy, 2003, 2006; Ersoy & Baki, 2004). The focus of the present study was to investigate the views and experiences of pre-service elementary mathematics teachers about using Classpad in learning algebra. In order to describe how pre-service elementary mathematics teachers perceive functions of a GC as an instructional tool, their use of GC, particularly the Casio Classpad, in the learning of algebra was investigated. Furthermore, it was aimed to explain how pre-service elementary mathematics teachers enhance mathematical meaning while working on elementary school level algebra tasks during a 5-week classroom-based study. In addition, at the end of the study, pre-service teachers' views on their experiences with the GC as an instructional tool in mathematics education and on the facilities and difficulties of using GCs were also aimed to be investigated.

## **1.2 Research Questions**

The following research questions guided this study:

1. What are the difficulties do pre-service elementary mathematics teachers face while using Classpad in learning elementary school algebra after receiving an instruction with graphing calculators?
2. What benefits and constraints do pre-service elementary mathematics teachers emphasize while learning elementary school algebra through using Classpad after receiving an instruction with graphing calculators?

## **1.3 Significance of the Research**

Investigating the pre-service and in-service teachers' attitudes and views in terms of using technology has been a common interest of a large number of educational researchers (Burrill et al., 2002; Dunkin, 1996; Ersoy & Baki, 2004; NCTM, 2000; Özgün-Koca, 2009). This study intends to focus deeply on the process of pre-service elementary mathematics teachers' use of a GC and on their views

which would present a different point of view about the GC use in mathematics classrooms for curriculum developers and teachers. In addition, investigating the advantages, facilities, obstacles and constraints that pre-service elementary mathematics teachers face in the learning of algebra by using Classpad, can provide important data and considerable results about how and why students should or should not use GCs in a specific mathematics subject. Namely, by mentioning the advantages, facilities, obstacles and constraints; the GCs' functions, menus, content, appropriateness with mathematical subjects, operating the tool and ease of usage are considered. Considering the reasons mentioned above, by giving detailed information about the GC usage processes of a group of pre-service elementary mathematics teachers, the results of the present study can be a guide for curriculum developers and teachers who are willing to adapt GCs into teaching of mathematics.

In Turkey information and communication technologies (ICT) are used in courses such as mathematics and physics in some private schools. The difficulties and effects of these applications can be helpful to develop an appropriate policy in favor of Turkey (Ersoy, 2007). In the reviewed literature, findings all meet at some main headlines which are the positive effects of GCs on student success and students' mathematical attainment with the help of GCs (e.g., creating visual understanding, raise in problem solving skills, higher achievement scores, better understanding of mathematical concepts) (Burrill et al., 2002). This study reveals how pre-service elementary mathematics teachers response in a lesson where the main tool is a GC and what they think after they learn algebra with the use of a technological tool instead of usual traditional approaches.

Algebra is chosen as the mathematical subject in this study since, when compared to other mathematical subjects, there are only a few studies on teaching and learning elementary school level algebra with the use of a GC (Burrill et al., 2002). Algebra is considered as a fundamental mathematical subject (NCTM, 2001; MEB, 2007) and it is a problematic area in mathematics education in terms of cumbersome calculations, drawing graphs, algebraic, making sense of the relationship between numerical and graphical representations (Drijvers & Doorman,



1996; Thompson & Senk, 2001; Westbury, 1992). Moreover, when GCs are used in the teaching of functions and variables, in solving algebra problems and interpreting graphs, students have a better understanding of the concepts related with those subjects (Graham & Thomas, 2000; Hollar & Norwood, 1999; Huntley et al., 2000; Quesada & Maxwell, 1994). Hence, because the use of GCs results in increase in the achievement level of algebra, mathematics teachers can benefit from the features of GCs such as mediating graphing activities, visualization, multiple representations, easy computation, and transformation (Hennessy et al., 2001; Özgün-Koca, 2009) in teaching and learning of algebra.

By providing data about the use of GCs in learning algebra with the first year pre-service elementary mathematics teachers whom will be the future teachers, the current study extend the studies which focus on elementary grade mathematics education with handheld graphing technologies. University education should provide pre-service teachers the opportunity to explore the role technology can play in helping them achieve their instructional goals; learn mathematics with a technology integrated program (Doerr & Zangor, 2000; Özgün-Koca, 2009). If they construct mathematical concepts in the courses engaged with GCs, they would see the benefits of technology in their education and they would be able to reflect these benefits when they become teachers. This would lead them to use technological tools such as GCs in the teaching of mathematics. To experience the role of technology in mathematics education more, technological tools should be integrated to university courses starting from the first year. Yet, first year students do not have technological pedagogical content knowledge (Koehler & Mishra, 2005; Niess, 2005, 2006, 2007; Özgün-Koca, 2009). They have not built a view on the significance of using GCs in mathematics education. They have not attended to any course related with GC use in mathematics; do not have any experience. Hence, they do not have any positive or negative view about GC integrated mathematics education. Not only having no experience in GC use in mathematics education; they also do not have any pedagogical knowledge regarding that. Their first experience in the mentioned areas was gained in the classroom studies conducted in the present study. Therefore, their

views, suggestions and evaluation on the use of GCs in a specific subject, which is elementary grade algebra learning area in this study, is considered to be valuable.

Being a qualitative study, this research makes a closer look into pre-service teachers' views about the use of a tool which is new for them in mathematics education by investigating their GC usage process. In addition, after they experience the learning and teaching process of a mathematical subject by having access to GCs, their detailed views of the process is intended to provide in depth information for teachers who are willing to adapt this new technology – the Classpad – into their classrooms for mathematics education. In addition, this study includes detailed lesson plans where the Classpad takes place as the main tool. Since algebra has a broad content, elementary school level algebra, covering grades 6, 7, and 8, is in the focus of the lesson plans of the present study. These plans are meticulously prepared examples for elementary school mathematics teachers. In addition, the results of the present study provides additional findings about the facilities and difficulties of a technologically equipped GC – the Classpad – which can be used to guide the developers of graphing technology supported tools for their future productions.

## **CHAPTER 2**

### **LITERATURE REVIEW**

In this chapter, the literature on the issues related to integration of GCs into mathematics instruction is reviewed. This chapter contains four groups of studies. First group of the studies investigates the GC use in teaching several mathematics subjects such as, functions, graphing, and algebra. Second group focuses on teachers' GC use in mathematics education. In the third group, studies related with the effect of GCs on students' learning of mathematical concepts in pre-college level are reviewed. In the last group of studies, the role of GCs in algebra is reported in the light of the related studies.

#### **2.1 Graphing Calculators In Mathematics Education**

Educators and researchers all over the world are heading towards change in teaching methods that have been used for years and no longer considered as effective in education (Burrill, et al., 2002; Ersoy, 2005; NCTM, 2000; Robutti, 2009). Among the different methods and techniques used in mathematics education, use of technology as an instructional tool is considered to be effective in learning (Doerr & Zangor, 2000; Ersoy, 2005; Kastberg & Leatham, 2005). Technological tools such as spreadsheets, GCs, dynamic graphing tools, computer algebra systems, dynamic statistical packages, data collection devices and, presentation software are considered as essential tools to be used teaching and learning mathematics (NCTM, 2003). Handheld GCs are considered to be useful and preferred tools in mathematics education (Ersoy, 2005; Mitchelmore & Cavanagh, 2000) for several reasons such as

being portable, manageable, available and functional (Doerr & Zangor, 2000; Kissane, 1995).

In mathematics education, mathematics teachers and educational researchers search ways to improve the students' understanding of mathematics by creating opportunities for interactions between the teacher and the student and among students. GCs, when used as an instructional tool, generates interaction between the students and the teacher and among students, which thereby increases mathematical learning (Drjvers & Doorman, 1996; Harskamp, Suhre, & Streun, 1998; Robutti, 2009).

In his study Ruthven (1990) focused on the effect of graphing technology use on students' understanding of mathematics by focusing on symbolization and interpretation items where students draw meaning from graphs and express them by using algebraic descriptions. In the study, it was found that if it is used in appropriate parts of the lesson, graphing technology would be beneficial for students' mathematical gains. Teachers are the decision makers of where and in which subjects the use of GCs will be effective for effective learning and teaching of mathematics. Heller and Curtis (2005) support GC use when needed, when teachers find it appropriate to use as an instructional tool during mathematics courses. In their study, some students had limited access to GCs in selected subjects that were generally suggested to be taught by GCs in the curriculum. Students who had limited access to GCs had higher marks from the achievement tests than the students who had full time access to GCs in all subjects during the lessons. The result shows that the limited and appropriate use of GCs provides more achievement than the full time use of GCs. In a study, Doerr and Zangor (2000) investigated a pre-calculus teacher and her students in two different classes in terms of their views on technology, use of GC and the roles they assigned to GCs. Similarly, Doerr and Zangor (2000) specified the use of GCs in mathematics courses such as "the calculator did not become a source of mathematical authority in the classroom" (p. 159).

A misunderstanding and prejudice about GCs is that GCs are the tools that only sketch graphs needing no mathematical knowledge of the user and there will be

no development in students' understanding by the use of GCs in mathematics education (Ersoy, 2003). Heller and Curtis's (2005) study is a counter example to this understanding. Students were not allowed to use any graphing technology during the end-of-course achievement tests which shows that although GCs were used frequently during the instruction, students gained basic algebraic skills well enough to get high marks in the achievement tests without using a GC. In another study, Robutti (2009) observed students working on modeling activities by using GCs and connectivity software at secondary school level. Students' construction of mathematical meanings was observed in a classroom environment. The results were classified into two; for the times students worked in groups with the connectivity software and the times they worked as individuals by their own GCs. GC was served as a private tool whereas connectivity software as a public tool. Having formed an environment both with GCs and connectivity software, the researcher observed signs in construction of knowledge where the latter provided social interaction leading a way to learning community. This multi modal design, that provides connectivity software use and GC use at the same time, is found efficient in terms of mathematical gains of the students.

Hennessy, Fung, and Scanlon (2001) conducted an interpretive study including a case study following a survey about the roles of GCs in mediating graphing activity. It was found that open-university students showed positive attitude on calculator integrated mathematics. Visualization, immediate feedback and less-time consuming were mentioned as the advantages of the calculators. Similarly, Özgün-Koca (2009) investigated the roles of GCs in the study conducted with pre-service secondary mathematics teachers on the use of calculators in mathematics instruction. The mentioned roles of GCs were visualization, transformation, computation, and data collection and analysis. The common outcome of the studies on the roles of GCs in mathematics education indicate that visualization feature of the GCs provide better understanding in the abstract concepts of mathematics. Moreover, in the studies mentioned above, quick computation facility and easy

sketching of the graphs provides increase in achievement in mathematics and saving time.

To strengthen the effects of GC use in education, Heller and Curtis (2005) conducted a study in a control group and experimental group design, in which all the students participated to the study used the same book during the instruction process. To omit the effect of the variations in the instructional context, the study was conducted during one academic year in Algebra I course which was considered as the basic course for learning advanced algebra skills in the future. The study investigated the factors in a classroom environment that changes the impact of using GCs on students' achievement in the selected algebra course. Participants were 11 teachers and 458 high school students of 21 class sections from four suburban schools in Oregon and Kansas. An end-of-course test –three parts measuring algebra knowledge and skills- and two teacher surveys –teacher background survey and classroom survey- were the data sources of the mixed method design. Three main results were drawn from the analysis of the data. Firstly, having more access to graphing technology increases students' achievement in Algebra I course. Secondly, test results of the students who were taught by a teacher that was trained in GC or computerized graphing technology use are higher than the test results of the students whose teachers were self taught in using graphing technology. Finally, students whose teachers were more experienced with the textbook got higher marks in the achievement tests.

## **2.2 Teachers' Use of Graphing Calculators in Mathematics Education**

For curriculum developers, students are in the focus when GCs are the matter of subject. In other words, they ignore the need for teachers to improve GC usage skills (Kissane, 2002). Mathematics teachers need development in terms of using GCs professionally in order to manage a classroom (Kissane, 2003), to guide and help students easily in every problematic situation that students pass through in experiencing with GCs. In addition, teachers should be well equipped with all the features of a GC to be able to create any activity with ease during a lesson and so for

the curriculum. In NCTM (2003) program standards for middle level mathematics teachers, use of technology is mentioned in the standards for initial preparation of mathematics teachers. It is expected from teacher candidates to be able to choose the appropriate technological tool such as spreadsheets, GCs, dynamic graphing tools, computer algebra systems, dynamic statistical packages, data collection devices and, presentation software to be used in the teaching and learning of every mathematics subject (NCTM, 2003). In order to meet the expectations of a qualified teacher in terms of using technological tools effectively, they should be provided the opportunity to explore the use of such technological tools in their educational life and see where and how technology helps them (Burrill, et al., 2002).

Kissane (2003) offers a theoretical model for teachers to progress in integrating technology in practical use appropriately. There are four stages of the model where each stage follows the other continuously. By passing first three stages (“Where is the ON Button?”, “Black Line Mastery”, “Routine Use” respectively) successfully, a teacher approaches to a professional stage called “What is in the Curriculum?” where GCs becomes a part of his/her daily use in education. It is evident in the literature that trained teachers in the use of GC and other technological tools use the tools more efficiently in the teaching of mathematics (Heller & Curtis, 2005; Ruthven, 1990).

A study (Laumakis & Herman, 2008) investigated the effect of a workshop called Increasing Achievement on Algebra Assessment (IAAA) for high school teachers on student performance where teachers use the TI-83 Plus handheld GC during the activities. Teachers used GC techniques that they had been learning in the workshop in their classrooms during a school year. There were two groups of students, one of the groups was thought by the teachers attended to IAAA workshop using GCs and the other group was thought by traditionally in a non-calculator environment. They got annual statewide testing. In the assessment part it was seen that the group of students thought by trained teachers had better scores than the other group. Similar to Laumakis and Herman (2008), Heller and Curtis (2005) found that algebraic test results of the high school students who were taught by a teacher that

was trained in GC or computerized graphing technology use were higher than the test results of the students whose teachers were self taught in using graphing technology.

If GCs are to be used in the mathematics classrooms, teachers will be involved in students' learning period of how to use those tools and help them in any obstacle they face. In addition to helping the students learn how to use the GCs, teachers need to prepare instructional tasks which can be carried out with calculator use. Therefore, in order to be effective in guidance of the students in the use of GCs and in preparing GC integrated lesson plans, teachers need to be experienced in handheld graphing technology use before they enter classrooms. In a comprehensive review of the research on handheld graphing technology in secondary mathematics instruction (Burrill et al., 2002), teacher training on the use of GCs is also emphasized.

“If change is desired, teachers need professional development that will help them feel knowledgeable about technology and that focuses beyond the functionality of the tool to incorporate the technology as a means of meeting mathematics learning goals.” (p. vii)

In the handbook (Burrill et al., 2002), after reporting a comprehensive review of literature in the area of GC integrated mathematics education, researchers recommended to study on pre-service teachers' views about the use of handheld graphing technology and how they would choose to use it in their classrooms. Teachers should be experienced enough to prepare lesson designs where they will make more benefit and effective use of technology. Confirming this claim, Li (2000) remarked that it is an important issue that pre-service teachers should learn the use of technological tools professionally in order to use them effectively in their classrooms when they become teachers. In similar, Ersoy (2006) suggests that pre-service teachers should be provided with the opportunity to gain experience, skills and knowledge in using GCs in the university courses such as teaching techniques and teaching practice. In these courses, pre-service mathematics teachers can gain experience while preparing GC supported tasks for elementary or secondary levels.



The studies, conducted in Turkey, about pre-service and in-service mathematics teachers' views about the use of GCs in teaching and learning mathematics are worth considering for the aim of this study. In Turkey, if GCs are to be used in schools to enhance mathematical learning, as it is in other countries mentioned above, teachers will be the guides of the effective use of technology who will decide why, when, how and where the GCs will be used. Therefore, as in other countries, pre-service mathematics teachers should be equipped with principal knowledge and skills to gain competence in using GCs confidently in mathematics courses and to be able to manage the GC adapted learning and teaching period. In order to provide teachers with these skills, they should be provided some experiences and opportunities during university education when they are pre-service teachers (Ersoy, 2006).

A reform in education can not take place by only providing teachers with GCs to be used in mathematics courses (Baki & Çelik, 2005). In order to adapt a new technology in education, teachers' views on the benefits of that technology are important (Özgün-Koca, 2010). Baki and Çelik (2005) conducted a study that focus on mathematics teachers' views on GC use in mathematics courses, especially in geometrical subjects. 14 mathematics teachers were introduced with a type of GC (TI-92) in GC integrated tasks and the process was observed. Two interviews were conducted before and after the study. In the interviews conducted before the study, it was seen that none of the teacher were aware of a technology called GC. Moreover, teachers believed that if students learn mathematics with the use of GCs, they would depend on the calculator and lack calculation skills. On the other hand, in the post interviews, teachers mentioned that GCs would be beneficial in terms of increasing students' interest and enhance active involvement in courses; therefore GCs would provide effective and permanent learning. Except 4 of the teachers, others believed GCs will encourage students to investigate mathematical concepts. Similar results were obtained from a study (Özgün-Koca, 2010) conducted with prospective secondary mathematics teachers who were not aware of the instructional material Computer Algebra Systems (CAS) used in the study. Prospective teachers' views on

the use of advanced calculators with CAS in algebra instruction were investigated. Before the study, teachers did not believe on any kind of use of the technological tool – CAS in algebra learning. After prospective teachers experienced CAS in algebra instruction, they shared the idea that students would be dependent on the calculator and can not develop skills. In addition, they expressed that CAS technology would be used after students gain some basic skills. It was reported that they were eager to own a calculator to use in their courses at university.

Johnson (2008) investigated the beliefs of 210 pre-service elementary teachers on the use of basic calculators in mathematics instruction. Many pre-service elementary teachers were opposed to the idea of using calculators in mathematics courses. The sources of their beliefs was found to be that they did not use calculators or other technological tools in their own elementary education in the past. The other reason was that they were uncomfortable in using calculators because they had little experience with calculators. Other teachers believed that calculators and other technological tools would enhance learning therefore should be used in mathematics instruction. However, they also added the use of the calculator should be controlled by the teacher in order prevent students depending on the calculators more than necessary. The additional result which was also mentioned in the previous studies that the introductory course that introduced calculators and included training period for pre-service teachers had positive effect on their views in terms of using calculators. Similar results were obtained from the study that Mason (2010) conducted with secondary mathematics teachers. Views of the teachers pointed that students' learning of mathematical concepts would increase with the use of calculators in mathematics instruction. Whereas, teachers doubt whether students lose basic skills if they depend on the calculator excessively. The crucial result derived from the study was that teachers should be prepared to teach in a technology-integrated environment with support and knowledge regarding calculators. In addition,

When the common results of these studies are considered, investigating the views of teachers and pre-service teachers reveal a crucial outcome that teachers

should have the opportunity to use of technology in mathematics education. Pre-service teachers should be provided with environments to experience technological tool particularly GCs to develop an understanding on the use of GCs in mathematics education (Johnson, 2008; Mason, 2010). Moreover, it was evident in the above mentioned studies that pre-service and in-service teachers' views effect their use of technology. Therefore, their views are worth to consider before and after they meet and experience with technological tools.

### **2.3 Graphing Calculators and Pre-College Level Students' Learning of Mathematics**

Technological productions develop faster and technology takes place more than the previous years in mathematics education all over the world. Among the technological tools GCs gain importance in mathematics education. With the help of calculators students are having the opportunity to work on real life problems (Drijvers & Doorman, 1996; Huntley, Rasmussen, Villarubi, Sangtong, & Fey, 2000).

In a comprehensive review on the relationship between the use of handheld GCs and mathematical achievement (Burrill, et al., 2002), GCs enhance learning, conceptual understanding and thus, achievement of pre-college level students.

In Turkish Elementary Mathematics Education Curriculum (MEB, 2007) it is suggested to use calculators in calculations and by referring to the time that students spend in long calculations, they can rather use that time to develop reasoning and creative thinking skills. As Ersoy (2005) mentions "technology is the most powerful force for curriculum influence today" and use of calculators and GCs in teaching and learning mathematics "is a reform movement" (p.1).

A modal was suggested by Mesa (2008) as the result of her study that provides conducting research about explaining the effects of technology in learning and instruction. Mesa (2008) investigated three combined fields: the strategies students choose as they solve problems on functions, differences between these strategies when GC is present or not and the role of the GC in the solution process.

Two problems were taken from a problem book on pre-calculus where all the problems were formed after a study on the effects of GCs on pre-calculus course. Problems were about symbolic representations of functions with parameters for the coefficients of the independent variable and graphs of polynomial functions. The problem set including two questions was prepared in two versions. In the first one, GC use was permitted for the first problem but not for the second one. In the second version, the conditions were reversed. The reason for this was to contrast the solution processes of problems when GC was used and not. Participants were 4 pairs of students majoring in secondary mathematics education. Researcher gave 9 problems to the class and selected the participants according to their willingness to use the calculator. Students offered different solutions to the questions and their participation to the class activities varied. TI-82, the GC produced by Texas Instruments, was used in the study. Participants' views on the problems and on teaching mathematics with GCs were gathered by a short interview. 8 protocols were obtained from the problem solving sessions – one protocol from each student. Data gathered from the videotapes of the sessions and researcher's field notes combined with the interview protocol. Mesa (2008) reported that students used the GC to compute their answers and to test their guesses on the coefficients of the equation they wrote for the given graphs. Presence or absence of the GC did not reveal any importance in the overall outcomes when the participants' problem solving strategies were considered. Another result that can be considered as an advantage of the tool was that students had the opportunity to test more functions in the same amount of time that they worked for the question. In addition to this, Mesa (2008) pointed out that GC filled the gap occurred from the lack of knowledge of connecting symbolic and graphical representations.

GCs are used as instructional tools in mathematics courses of most of the schools in the United States. According to the survey outcomes of College Board commission regarding high schools, the need and active use of GCs is reported to be in 87% of the mathematics classes (Dion, Harvey, Jackson, Klag, Lui, & Wright, 2001). Mesa (2008) indicated, "GCs have become part of high school mathematics

classrooms” and added that in most of the high school algebra and geometry classes, teachers use GCs extensively. Considering the issue that GCs are being used in secondary level frequently, there occurs a need to investigate the role of the GCs in one step back which is elementary level in 6<sup>th</sup>, 7<sup>th</sup> and 8<sup>th</sup> grades. In addition, Laumakis and Herman (2008) suggested that it will be useful to get detailed information from students in terms of using GCs in the classrooms during learning of upper level mathematical courses. Considering the recommendations and gaps in these studies, it can be expressed that there is a need focusing on detailed views of students, pre-service teachers and teachers in technology integrated elementary level mathematics education.

#### **2.4 Role of Graphing Calculators in Algebra**

Identifying algebraic expressions with visual expressions such as relating equations with graphics and figures. This is specified in Turkish Elementary Mathematics Education Curriculum (MEB, 2007) in the basic aims of the algebra learning area. In the elementary level, from sixth to eighth grades, teachers aim to acquire students to generalize the rules in the patterns and express them by using letters. The equations with two unknowns follow the generalization of the rules. These acquirements help students to develop the needed abilities to prepare a basis for understanding the functions concept in further grades. In developing concepts related with algebra, the variables concept also gain importance as elementary grade students start to use another language in expressing several mathematical cases, formulas, algebraic expressions, and equations (MEB, 2007).

In the existing study, the aim of choosing algebra learning area is that algebra is a subject which is considered as the base of most subjects in mathematics education (NCTM, 2003). The other reason is that algebra is a suitable subject with all its sub branches to be taught with GCs (Heller & Curtis, 2005; Burrill, et al., 2002) especially with the broad content, menus, and features of the GC – Casio Classpad 330. Research related with the relationship between algebra and GCs found that calculator technology adapted instructions is beneficial in the understanding

algebra subjects (Graham & Thomas, 2000, Hollar & Norwood, 1999; National Research Council, 2001).

It is mentioned in the Turkish Elementary Mathematics Education Curriculum (MEB, 2007) that in teaching the two sub learning areas of algebra, which are algebraic expressions and equations, using multiple representations approach will provide a meaningful understanding environment for learners. In the curriculum, multiple representations concept is defined as an approach which is based on expressing a situation or a concept in different forms. In the teaching and learning process, if students express mathematical concepts by using symbols, graphs, tables, real life situations and concrete models, this will produce qualified learning.

In the curriculum it is emphasized that the sub-learning areas of algebra; equations, tables and graphs should be related with each other by forming meaningful connections between them. GCs are the suggested tools to be used in the teaching of algebra, as they include applications related with multiple representations approach (MEB, 2007).

Considering the detailed review of the literature about using GCs as a mathematical tool in pre-college level education, studies generally focus on function and graph related subjects (Doerr & Zangor, 2000; Forster & Mueller, 2001; Guin & Trouche, 1998; Hennessy, et al., 2001; Lauten, Graham, & Ferrini-Mundi, 2000). This reveals a gap in investigating the use of GCs in a mathematical subject that does not include only graphs. Moreover, the review of the literature about using GCs as a mathematical tool in elementary level education indicates that studies generally focus on function and graph related subjects (Lauten et al., 1994; Mesa, 2008; Ruthven, 2010). This reveals a gap in investigating the use of GCs in a mathematical subject such as algebra that does not only include graphs.

## **2.5 Summary of the Literature**

Technology has been adapted to mathematics education and especially GCs are used frequently in mathematics teaching and learning all over the world. In many

studies it has been concluded that GCs enhance mathematics learning of students by the features they obtain such as visualizing, computing, graphing, and sketching (Doerr & Zangor, 2000; Ersoy, 2005; Kastberg & Leatham, 2005; Mitchelmore & Cavanagh, 2000).

Teachers' use of technology and their views on the use of technology in education have been valued as important when the use of technology in mathematics classrooms is considered. It has been indicated by many researchers that teachers' use of technology effect their classroom habits and teachers' views on technology incline their technology use in mathematics classrooms. Hence, teachers' views on the use of GCs in mathematics education differ according to their experiences with technology (Baki & Çelik, 2005; Özgün-Koca, 2010).

Algebra is a branch of mathematics that is reported as students have low achievement scores, understanding problems, and misconceptions (Dahland & Lingefjard; 1996; Forster & Mueller, 2001; Graham & Thomas, 2000; Huntley et. al., 2000). As a solution to the problems that students face while learning algebraic concepts, use of GCs in teaching and learning of algebra is suggested in some studies. The features of the GCs' such as visualization, multiple representations, transformation, and computation are indicated as the qualities that would help students in over coming the difficulties they face while learning algebra (Doerr & Zangor, 2000; Forster & Mueller, 2001; Hennessy et al., 2001; Özgün-Koca, 2009).

Considering the reasons above, pre-service elementary mathematics teachers' experiences on the GC Casio Classpad 330 and their views on the process of learning algebra via the use of the tool is considered to provide important data for the aim of this study. In addition, the main subject of the study was determined as elementary level (grades 6,7, and 8) algebra learning area.

## **CHAPTER 3**

### **METHODOLOGY**

This chapter outlines the methodology of this study investigating the views and experiences of pre-service elementary mathematics teachers on the use of a GC – Classpad (CP) – in mathematics teaching and learning. The chapter presents the research design, data collection procedure, data analysis procedure, validity and reliability of the study, and limitations of the study.

#### **3.1 Research Design**

In this study, qualitative research strategies were used so as to collect and analyze the data to reveal the views of pre-service elementary mathematics teachers on the use of GCs.

The data was collected and described by means of case study design which is based on qualitative methods design to investigate the views of first grade elementary mathematics pre-service teachers in the use of CP in a university mathematics course in learning elementary level algebra. Yin (2003) describes case study as; “an empirical inquiry that investigates a contemporary phenomenon within its real life context, especially when the boundaries between phenomenon and context are not clearly evident” (p. 13). The use of the handheld GC CP was observed in a first grade course at university level. The reason for selecting the case study approach was to be able to investigate and observe the students in their usual classroom environment. In addition, Yin (2003) also mentions that;

“The case study inquiry; copes with the technically distinctive situation in which there will be many more variables of interest than data points, and as one result relies on multiple sources of evidence, with data needing to converge in a triangulating fashion, and as another result benefits from the



prior development of theoretical compositions to guide data collection and analysis.” (p. 13-14)

With these words in mind, data set was gathered from classroom observations, open-ended questions and clinical group interviews of the pre-service elementary mathematics teachers in order to obtain a data set from multiple sources. As an additional data source, three attitude scales on mathematics, technology and learning algebra with CP were conducted before and after the treatment. These attitude scales were analyzed by quantitative methods and the results of the analysis of these three attitude scales were used only to form the interview groups.

In this study, the participants were 21 pre-service elementary mathematics teachers forming one single group. They were observed during a treatment period followed by focus group interviews. Triangulation of three data sources - the observation of students’ work, open-ended questionnaire and focus group interviews - was used for in depth analysis of pre-service teachers’ views on the use of GCs.

### **3.1.1 Participants**

According to Yin (2003) “the ‘case’ also can be some event or entity that is less well defined than a single individual. Case studies have been done about decisions, programs, the implementation process, and organizational change” (p. 23). In this study, the case was formed by a group of 21 pre-service elementary mathematics teachers who had a five-week treatment period on the use of a GC CP in elementary level algebra teaching and learning. In the light of Yin’s view, an implementation process was carried out, where elementary level mathematical subject algebra was thought to 21 pre-service teachers by using a handheld GC, CP.

As the participants of this study, 21 pre-service teachers from Elementary Mathematics Education department in a private university in Ankara were chosen. Students who were chosen to be included in the data collection process were in the first year of their university education. They all took one mathematics course – General Mathematics – in their first semester and two mathematics courses – Geometry I and Discrete Mathematics – in their second semester while the study was

being conducted. Among all, one of the participants, P4, has a different educational background than the other 20 participants in that he had three years of education in another university at the department of mathematics before he started his pre-service teacher education at the private university. He was older than the other participants. Another difference was that he has been giving private mathematics courses to high school students for two years. There are 16 female and 5 male pre-service teachers participated in the study; 76.2 % female and 23.8 % male. Demographic information of the participants in terms of age distributions is given in Table 1.

Table 1. Age distribution among the participants

Age	19	20	21	22	29	Total
n	3	7	6	4	1	21
%	14.3	33.3	28.6	19.0	4.8	100

The research was conducted with a convenient group of first grade pre-service elementary mathematics teachers who were not familiar with a GC. The study took place in a course called Computer Supported Education (CSE) which is compulsory for all students at the faculty of education and elementary mathematics pre-service teachers are taking this course at their first year in university. The researcher was the teacher of this course.

There were 50 first grade pre-service teachers at Department of Elementary Mathematics Education at a private university in Ankara during the 2009-2010 academic year in which the study was conducted. There were two sections of the CSE course. In one of them, 30 pre-service elementary mathematics teachers were enrolled. The other one was a mixed section formed of the rest 20 pre-service elementary mathematics teachers and 10 pre-service pre-school teachers. Therefore, the first section, as it was formed with only pre-service elementary mathematics teachers, was considered appropriate for the research to be conducted.

Prior to the selection phase, students were informed about the tool and the five-week instruction period. Furthermore, all 30 students were told that the remaining 9 students would be able to complete the course with the other section

where the instruction was going to be the same as the previous courses. In the other section of the course, there were the remaining 20 elementary mathematics pre-service teachers where the lecturer was also the researcher herself. Therefore, the students who did not volunteer to participate in the research period were provided to complete the course with the same teacher and so were not afraid of being graded unfairly. Hence, it was guaranteed that participants volunteered for the aim of meeting with the GC CP and using it in the elementary level algebra subject for a five-week period.

29 out of 30 pre-service teachers who were in the first section of the course volunteered to participate in the study. The aim was to conduct the study with all of the voluntary students disregarding the number of volunteers even though their number was low. However, the number of voluntary participants exceeded the number of the GCs available. Therefore, out of 29, 8 of them were eliminated randomly. The reason for conducting this study with 21 participants was that there were 23 GCs available at the time of the instruction period. One of them was for the teacher, and the other one was hold as a spare one for a possible fault in other tools.

The researcher has been working as a research assistant at the department of elementary education for two years. In addition, researcher was the instructor of the first grade pre-service elementary mathematics teachers in the CSE course. Therefore, they were an accessible group of students to conduct the study. Fraenkel and Wallen (1996) define a convenience sample as “a group of individuals who conveniently are available for study” (p. 99). The obvious advantage of this type of sampling is that it is convenient (Fraenkel & Wallen, 1996), as it was easy for the researcher to approach the research area, to get permission for the research to be conducted and to communicate with the students and to arrange the content and flow of the course independently. Researcher had familiarity with the students, with the course and with the university, since she was the instructor of those students in the first part of the same course (CSE I) in the previous semester, too.

Fraenkel and Wallen (1996) explain purposive sampling as “based on previous knowledge of a population and the specific purpose of the research,

investigators use personal judgment to select a sample” (p.100). According to them, researchers can use their knowledge of the population to judge whether or not a particular sample is appropriate for the aim of the study. In the current study, researcher knows the demographic, personal, and background information of the mentioned students, as she was their teacher for approximately two semesters. In this study, the researcher did not “simply study whoever is available, but used judgment to select a sample, based on prior information, will provide the data needed” (p.101).

In addition to being convenient, first grade pre-service elementary mathematics teachers who were selected to be the participants of this study as they were appropriate for the aim of this study. The reason of choosing first grade pre-service elementary mathematics teachers was that they were at the very first step of being teachers of future. Participants had not received any pedagogical knowledge prior to the study as they were in their first year in university. For this reason, it was believed to provide more accurate views about their personal use of GC during mathematics instruction both in their level at university and in elementary grades of 6, 7 and 8. Besides, it is obvious from the previous studies that attitudes of teachers towards technology have an important role in mathematics education (Guin & Trouche, 1998; Hennessy et al., 2001; Mitchelmore & Cavanagh, 2000). Likewise, the participants of this study had just finished their 12-year education without having an opportunity to use any kind of instructional technologies. Therefore, first year pre-service teachers’ attitude on technology and mathematics was considered to be important for the aim of this study.

### **3.1.2 Setting**

This study was conducted during the 2009-2010 education year, fall semester, in Computer Supported Education (CSE) course which is a course taken every year by the first year students of elementary mathematics education program at the university.

The reason of selecting the CSE course to conduct the current study was that during the usual flow of the course, students bring up all their mathematical and

technological knowledge to produce and create different teaching ways and materials. Firstly, students search the subjects and content of elementary level mathematics curriculum of grades 6, 7, and 8. Secondly, they choose one subject, which they consider as appropriate to be combined and thought with the current available computer programs. These programs can be listed as; MS Word, Excel, Power Point, the Geometer's Sketchpad, online mathematics programs, interactive mathematics games. Therefore, CP was a mathematical tool for them to be used as an instructional tool in CSE course.

Instruction took place in two computer laboratory classes – two hours in one of the classes and two hours in the other in a week. The classrooms were equipped with computers for students, a computer for the teacher and a projector connected to the teacher's computer.

Projector was always on during the course hours to transfer the visual CP on the desktop to the wall with the help of a computer software called CP manager which has exactly the same visual appearance and functions as a handheld CP. Hence, CP was installed to the instructor's computer.

### **3.1.3 The Role of the Researcher**

The researcher was the instructor in the study. This selection of the participant-observer role enabled the researcher to observe the students in multiple points of views (teacher, researcher, member of the class) and to observe the interactions with and among the students directly.

The students were familiar to the researcher as they attended a computer course in the previous semester in which the researcher was also the instructor. Consequently, the researcher had familiarity with the participants prior to the study. Therefore, there was a close relationship between the members of the group to express their ideas comfortably. The familiarity between the participants and the instructor and among the participants made the observation and the interview period more reliable as the researcher was able to understand what the participants meant and thought when they expressed themselves by words or behaviors. Moreover,

students felt comfortable to express themselves freely as they were used to the researcher and to each other for a year.

The familiarity of the researcher with the tool was a 2 year-period where the researcher trained herself from the tutorial books of CP and from the documents in the web site of the tool. The web site of Casio Classpad consists of online tutorials and several activities in pre-college and undergraduate level of mathematical subjects. By completing several tasks on the web site and in the tutorial books in two years, the researcher was comfortable in using all the menus of CP in the time of the study.

### **3.1.4 Lesson Plans**

In order to examine pre-service elementary mathematics teachers' use of the GC, it was important for them to be aware of the basic use of the tool, its features, content, and technical limits. In this study, one-week training period on the GC and the tasks in the instruction period were prepared according to the ways in which participants typically use the calculator in the previous studies (Dahland & Lingefjard; 1996; Guin & Trouche, 1998; Simonson & Dick, 1997).

The main and common purpose of the lesson plans in this study was to enable the participants overcome the conflicts such as identifying and connecting algebraic expressions with visual expressions like relating equations with graphics and figures. The connection between multiple representations is also specified in Turkish Elementary Mathematics Education Curriculum (MEB, 2007) in the basic aims of the algebra learning area. In the basic aims, it is mentioned that algebra learning area is the subsequent of the sub learning area patterns which takes place in the first to fifth elementary grades curriculum. In the following grades of the elementary school after the first five grades, in general, teachers aim to help students generalize the rules in the patterns and express them by using letters. The equations with two unknowns follow the generalization of the rules. These acquirements help students to develop the abilities needed to prepare a base for the understanding of the concept "functions" in further grades. In developing concepts related with algebra, the

concept “variables” also gain importance as elementary grade students (6-8<sup>th</sup> grades) start to use another language in expressing several mathematical cases, formulas, algebraic expressions, and equations. Therefore, variables have a crucial role in learning algebra (MEB, 2007).

It is mentioned in the Turkish Elementary Mathematics Education Curriculum (MEB, 2007) that in teaching two sub-learning areas of algebra, which are algebraic expressions and equations, using multiple representations approach will provide a meaningful understanding of the environment for learners. In the process of teaching and learning, if students express mathematical concepts by using symbols, graphs, tables, real life situations and concrete models this will produce well-qualified learning (MEB, 2007).

In the lesson plans, meticulously prepared tasks were included in the instruction for the participants to investigate the connections between the GC expressions and their existing algebraic mathematical knowledge. Tasks and activities that can be conducted with the use of CP were prepared. They were parallel to the problems which elementary students are expected to solve by traditional ways without using a GC according to the curriculum. By selecting questions such as these, participants’ ability to use CP and to interpret the results represented in the CP was aimed to be observed.

Expert opinion was taken for each lesson plan that was prepared. Lesson plans were presented to two researchers. One of the expert researchers was an assistant professor in mathematics education. The other researcher was about to complete her doctoral degree in secondary mathematics education. Scholars expressed their opinions on the clarity and content coverage of the tasks in the lesson plans. Accordingly, the lesson plans were improved and finalized.

In the lesson plans, there was variety of questions. They were related with the algebra sub-learning field of Turkish Elementary Mathematics Education Curriculum. Mathematical problems, tasks and activities in every lesson plan were prepared meticulously by considering the background of the elementary level students and tasks in the lesson plans adhere to and cover all the objectives of

algebra subjects in the 6<sup>th</sup>, 7<sup>th</sup> and 8<sup>th</sup> grades. The aim was to form an actual adjustment between the lesson plans and Turkish Elementary Mathematics Education Curriculum. The correspondence of the lesson plans with the curriculum is presented in Table 2 below.

Table 2. Table of specification

<b>Learning Area: Algebra</b>		
<b>Lesson Plans</b>	<b>Sub-Learning Areas</b>	<b>Grade</b>
Lesson 1	Patterns and Relations Algebraic Expressions	6
Lesson 2	Patterns and Relations	6
Lesson 3	Patterns and Relations Algebraic Expressions	6
Lesson 4	Exponentials Patterns and Relations	7 8
Lesson 5	Algebraic Expressions	7
Lesson 6	Equations Algebraic Expressions	7 8
Lesson 7	Equations	7 and 8

Lesson plans follow a specific path as they follow several steps. Firstly, since the participants are pre-service teachers knowing elementary level algebra very well, explanation of the subject was held brief and short. The introduction part aimed to show the participants how to introduce a subject to elementary level students with a technology supported lesson plan.

Secondly, class discussions for sharing the solution process and explaining results took place during the courses as a separate part of the lesson plans. Participants were assigned to work on the presented tasks both individually and in groups. After working on each problem, they were introduced to a group discussion in the classroom, where all of them presented their ideas to the whole class. The aim



of this discussion period was to make participants to share their results and the steps which took them to the result with each other as well as to express their ideas about learning algebra with CP. Therefore, the content of group discussion includes sharing the solutions with other students, making comments on different ideas – whether they agree with their peers or not – and expressing the thoughts about the usage of CP in the related problems. A typical lesson design is given below in Table 3.

Table 3. Lesson outline

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**Recall process** (5 min. approximately)

Reminding the main points of the previous lesson.

Having students explain and summarize what they have learned so far related with the functions of CP.

According to the answers, if needed, teacher presents an example about the previous courses.

**Warming up** (10 min. approximately)

Teacher asks open-ended and non-directing questions to understand the background information of the students about the subject.

Teacher reminds the main points of the related algebra learning outcome of the course. As the participants are pre-service elementary mathematics teachers, they are expected to have complete knowledge of elementary level algebra content. Therefore, there is no need to teach the content of the learning outcomes in detail.

Firstly the related subject is summarized by using the blackboard and by lecturing. After that, one of the below choices is conducted to prepare students for the CP activity.

Teacher asks questions and gives daily life examples about the subject. This creates question marks in students' minds, which leads a desire to pay attention to the rest of the lesson.

Building a bridge between the previous and new subject takes place by explanations or questions. By matching the subjects, teacher encourages students that the new subject is not difficult. In this step students start to wonder how the

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Table 3. Lesson outline (Continued)

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related subject will be instructed with CP.

Teacher presents an opening activity by using CP or other instructional tools such as paper-pencil. A short-time activity prepares students' minds for the new subject. After the examples and other teaching activities, teacher gives the topic and basic information about the subject of the lesson referring to the examples they have just worked on. This provides a readiness for the upcoming activity.

**Teaching and Learning Period** (30 min. approximately)

Activities, prepared prior to the courses, are presented to class including directions. In the first two weeks of the instruction period, activities are presented with the steps needed to complete the activity. In the rest of the instruction period, activities are presented by leaving the solution process completely to the students. Students are responsible of selecting the appropriate menus, functions and steps in order to find solution to the given situation.

Students are presented with problems prepared by the instructor. Problems have some basic qualities such as leading students to thinking, including daily life situations, being parallel with the problems suggested in the Turkish Elementary Mathematics Education Curriculum and including main points of the related subject. The main tool that the students work with during the activities is a GC - Casio Classpad 330 Plus (CP). Problems are prepared as compatible with CP.

Students think about the problem and share their ideas about the solution process. Students work individually or in pairs (changes according to the difficulty level of the activity). Students are encouraged to express their ideas, share their solutions with each other as the activity continues. Teacher walks among the students and asks directing questions if there are students who are having problems in progressing the task (understanding the question, using the tool, expressing ideas). After thinking and creating solution ways, a whole group discussion as a class takes place with the guidance of the teacher. Teacher provides a discussion

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Table 3. Lesson outline (Continued)

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environment near the end of the activity time as the students show considerable progress. Every student is expected to explain his/her idea about his or her solution process. Hence true answers are reached. In order to explain the main points of the subject, teacher goes over the solutions of the problems and mentions all the details about the steps relating with the subject and CP.

Students are expected to find solution ways with the use of CP. Teacher's guidance takes place in every period of the problem solving process when students have difficulty in finding a function of a menu.

**Closure** (5 min. approximately)

Reinforcing the subject is provided by meticulously prepared short-time activities which have similar qualities with the ones in the teaching and learning period of the course.

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During the classroom studies, participants were not expected to find the right menu or button on the tool to progress in the given task. The instructor always helped them to find the related menu, necessary shifting, and buttons. What was left to the participants was to decide the correct steps to reach the result, carry the given data on CP and find the result. This was the case at the beginning of the instruction process; however, as the courses continued, participants started to use the tool more confidently and independently almost without the guide of the instructor.

### **3.1.5 Treatment**

In this research, the case was formed by a group of 21 pre-service elementary mathematics teachers who had a five-week treatment period by the researcher as the instructor. Participants did not have any experience on handheld GCs before this study. Prior to the four-week instruction, a six-hour training program on the use of CP was given. Participants were instructed about how to use CP and they carried out all the tasks in the instruction period. By investigating the manuals, online tutoring videos, introduction kit of CP on Casio website (classpad.org), the content of the

training program was prepared. The activities in the training period covered all of the menus of CP to help the pre-service teachers gain confidence in using the tool. Nonetheless, most of the activities were conducted by using four of the menus of CP (main menu, graphs and tables, e-activity, and geometry) that was going to be frequently used in the instruction period while working on the algebra tasks. Although 4 menus among 16 were frequently used during the study, all 16 menus were introduced to the participants at the training period.

The training included the following topics:

- A brief explanation of handheld GCs
- A general look into the CP
- Functions of the calculator
- Introducing 16 menus of CP
- The usage of the calculator for a specific topic: Algebra
- Examples and applications on 4 menus related with algebra

A student who is not used to CP would not like to use it in learning mathematics and would not intend to solve mathematical problems through CP. Students should feel comfortable and self-efficient in using CP. For this reason, the basic aim was to make students feel comfortable when using CP in algebraic tasks rather than to present them all of the mathematical features and capabilities of CP in detail.

Firstly, buttons that are commonly used almost in every mathematical task were introduced. Moreover, a brief explanation was given to introduce the capabilities of the GC Casio Classpad 330 to the participants.

Following the explanation of the menus and their functions one by one, mini exercises including the directions were prepared to lead students to discover the menus. The exercises in the original tutorial of Casio CP ([classpad.org](http://classpad.org)) was used in the training period. Afterwards, participants were asked to explain simply what was there in the GC.

### 3.1.6 The Graphing Calculator: Casio Classpad 330

The tool Classpad that was used as the main instructional tool in the current study is a Casio product which is equipped with nearly all the menus of the tools that have previously been produced as GCs. In addition, classpad has newly formed menus such as the menu spreadsheet related to mathematics and other science branches such as physics and statistics.

Figure 1 shows the physical appearance of the tool and the menus it includes. The menus of CP are; main, e-activity, statistics, graphs and tables, sequence, conics, 3D graph, geometry, numeric solve, presentation, program, communication, and system.

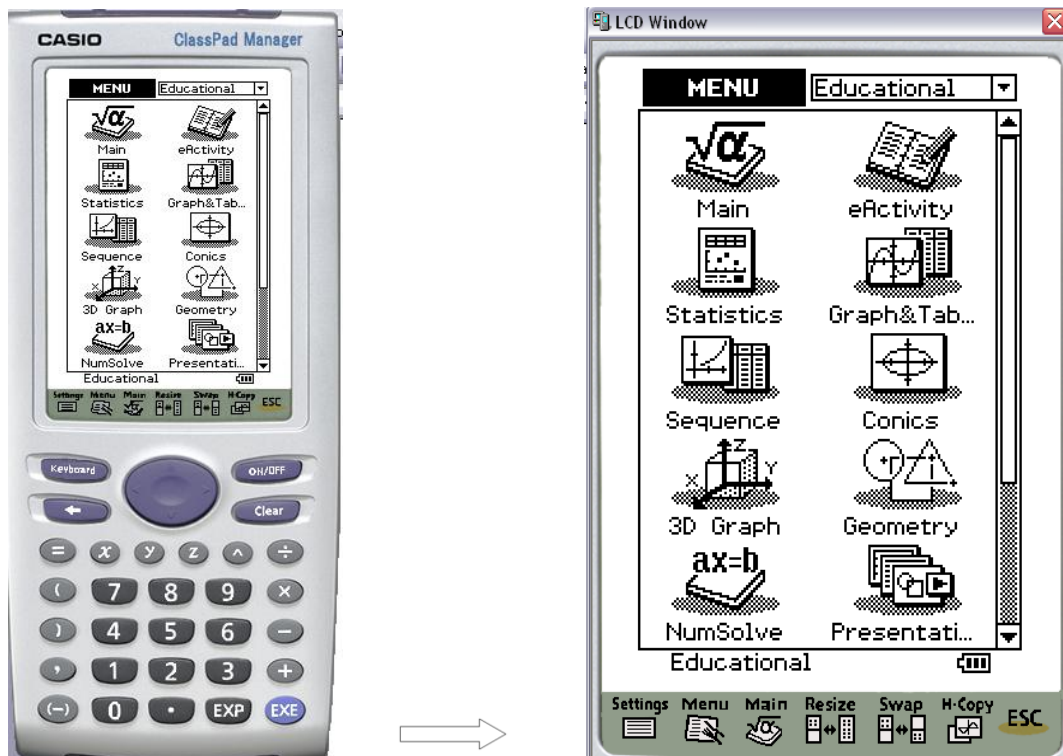


Figure 1. Visual appearance of Casio ClassPad 330

When Turkish Mathematics Education Curriculum was investigated, four menus were considered to be related with the subject algebra in elementary level – grades 6, 7, and 8. These were, main menu, geometry, graphics and tables, and e-activity.

Main menu contains basic calculations that a usual calculator is capable of doing such as multiplication, division, addition, subtraction, roots of numbers, and fractions. In the menu geometry, there is a window including ready-shapes in geometry and virtual buttons for construction of figures. In graphics and tables, there are several functions for solving equations, graphing, table of values and transformation. E-activity is the menu where all of the functions above can be brought together in order to prepare combined activities and to solve complex problems (See Appendix B for detailed information about the four menus).

### 3.2 Data Collection Procedure

Data in the current study was collected during the course named as Computer Supported Education (CSE). In the context of this course, students are expected to examine Turkish Elementary Mathematics Education Curriculum (grades 6, 7, and 8), select learning and sub-learning areas from the curriculum and develop tasks and activities on the subject they selected. The data collection procedure of this study is presented in Table 4.

Table 4. Procedures

Before the Treatment	Sensual Tests: • Thee Attitude Tests (Mathematics, Technology, Learning Algebra with GC)
Treatment (1 month – 16 course x 50 min)	• Observation (video-taped) • Observation notes
After the Treatment	• Three Attitude Tests (Mathematics, Technology, Learning Algebra with GC) • Open-ended questionnaire (5 questions) • Focus Group Interviews

Prior to the instruction process, the participants of the study filled out the attitude scales in a course hour. Later on, a training lasted for four hours was given to the participants. After that, by following the lesson plans participants were instructed with elementary level algebra by using CP as the main instructional tool for four weeks. When the instruction period was completed, the participants were given three attitude scales on technology, mathematics and learning algebra with CP as post-tests. According to the quantitative data, interview groups were formed. One week after the instruction was completed, three focus group interviews were conducted with the selected participants.

### **3.2.1 Data Collection Instruments**

Classroom observations, group interviews and an open-ended questionnaire were employed to gather qualitative data. Three attitude tests on mathematics, technology and learning algebra with GC were used to form the interview groups in this study.

The purpose behind the interviews following the observation process was to support the data obtained through the classroom observations. This data collection method is explained by Fraenkel and Wallen (1996) as follows:

“Certain kinds of research questions can best be answered by observing how people act or how things look... Interviewing is an important way for a researcher to check the accuracy of – to verify or refute – the impressions he or she has gained through the observation.” (p. 446, 447)

Similar to this view, analysis of the interviews provided supportive data that clarified participants’ behaviors and statements in the classroom observations. Furthermore, during the focus group interviews, participants made additional explanations about their statements in the classroom studies which increased the accuracy and trustworthiness of the results.

#### **3.2.1.1 Observations**

In the study, there had been a four-week instruction and observation process. There were four course hours in a week and one course lasted for 50 minutes. The

researcher was involved in the instruction process as a participant observer. The instructor was the researcher. In order not to miss out any data during the lessons, instruction process (16 courses x 50 min in total) was video taped during the four weeks of data collection process.

Recording was carried out through two video recorders, one of which was stabilized in the corner of the classroom in such a way to view the whole class; the other one was mobile. In other words, the person who carries the mobile hand camera randomly chose participants and zoomed in and out the participants and their CP screens. People who helped in the close camera shot were four research assistants from elementary education department, one university senior year student from business and management department and a retired elementary grade teacher.

During the classroom observations, participants were examined according to five situations listed below:

- Participants' interaction with the GC CP.
- Behaviors and statements of the participants about the process and the GC CP.
- Active participation during the instruction.
- The difficulties that participants face related with the GC CP.
- Role of the GC CP in participants' learning.
- Questions that participants asked to the researcher and to each other.

The researcher took notes after each two-hour course sessions. Notes were related with the five situations listed above and were written down in order to record the immediate investigations of the researcher about each course.

#### **3.2.1.2 The Questionnaire**

A questionnaire including five open-ended questions covering the five weeks - one-week training and four-week treatment period - were prepared by the researcher. The questions were prepared considering the purpose and research questions of the study. In addition, the data in the researchers' observation notes



were reviewed and the questionnaire was shaped according to the participants' views and the way they treated to CP during the classroom observations. These questions were sent to the participants by e-mail and they answered the questions immediately after the last course. Answers of these questions were analyzed to support the results and also used to shape the interview questions. The questions in the questionnaire were as follows:

1. What contribution did CP provide you in learning algebra?
2. What obstacles did you face while using CP in learning algebra?
3. What are the advantages of using CP while learning algebra?
4. What are the disadvantages of using CP while learning algebra?
5. What other things would you like to add about the GC - CP?

### **3.2.1.3 Interviews**

Participants' views on the effectiveness of the teaching and learning process with CP, the difficulties they faced while working with CP and their ideas on the appropriateness of the tool to mathematical subjects were revealed with there focus group interviews. 14 out of 21 participants were interviewed at the end of the instruction and the interviews were video-taped.

Focus group interview was employed in this study. Wilkinson (2004) gives the basic characteristics of a focus group interview as follows:

“A focus group project can involve a single group of participants meeting on a single occasion, or it can involve many groups, with single or repeated meetings. It can involve as few as two, or as many as a dozen or so, participants (the norm is between four and eight). These participants may be pre-existing groups of people or they may be brought together specifically for the research, as representative of a particular population, or simply on the basis of shared characteristics or experiences.” (p. 178)

In this study, three groups were formed for the interviews, which had three, four and seven participants, respectively. Participants of the study were the existing first grade pre-service elementary mathematics teachers in the private university who shared similar experiences in five weeks instruction period. In addition, the three interview groups were formed to bring the ones who had similar qualities in terms of

their attitudes towards mathematics and technology. Another reason of conducting focus group interviewing was to provide participants a discussion environment to exchange their experiences with each other and as Kastberg and Leatham (2005) emphasized, this environment would give them the opportunity to express their personal views about mathematics teaching and the tool CP.

The interview questions were constructed in line with the goals of the study and the questions in the related studies (Burrill, et al., 2002, Özgün-Koca, 2009, 2010). Questions were prepared under three main titles namely, using CP in learning algebra, both technologic and functional facilities of CP and views for a more facilitated GC. For the wording quality, clarity and content coverage of the questions, three researchers were asked to evaluate the questions and express their opinions. One of the researchers is an assistant professor studying in assessment and evaluation and research methods. She has several qualitative studies in education. The other two researchers have masters' degree on science teaching and assessment and evaluation, respectively.

After the questions were revised according to the expert views, three pilot interviews were conducted with one of the participants who was not included in the interview groups, with a university student from elementary science and mathematics teaching department and with a high school student in 10<sup>th</sup> grade. The pilot interviews were carried out in order to find out possible problematic parts of the questions and to improve them for a clearer and better understanding. At the end of the corrections considering the opinions of the experts mentioned above, necessary changes in the interview questions were made. 5 main questions and several follow-up questions to gather complete information formed the interview question list of this study (See Appendix D for the interview questions).

As Vanderstoep and Johnston (2009) mentioned, interviews should be conducted by covering three parts: setup, building of rapport, and closing, which are important for the effective relationship between the interviewer and the respondents. In order to provide a setup, participants were informed of “the roles and expectations for the interviewer and interviewee” (p. 226). The aim of the study was

reminded to the participants at the very beginning of the interviews. In addition, they were informed that they should feel comfortable to express their thoughts without the fear of making any mistakes and providing with incorrect information or ideas, as everything they utter to answer the questions are valuable for the outcomes. They were also convinced that they would not be graded according to the interviews, any of their comments were welcome about the instructional tool CP and their thoughts were valuable since they were the teachers of the future. They were also informed of the estimated length of the interview, half an hour for the two groups and an hour for the third group. As participants were informed as stated above, this “helps the respondent know how to act, reduces apprehension, and helps to establish rapport with the respondent.” (Vanderstoep & Johnston, 2009, p. 226)

Participants were listened with interest, respect, appreciation and acceptance and verbal feedback was rarely used not to change the focus of the interviewee as Vanderstoep and Johnston (2009) suggested. In the closure part of the interview, the researcher should “bring the respondent back to the present environment. The skillful interviewer gradually decreases the intensity of the questions in the closing process” (p. 227). Therefore, as the closing question, ‘Is there anything else that you would like to add?’ was asked. It was also told that participants can approach the researcher whenever they want in any situation they would like to share. As the researcher is a teacher in the same school with the participants, they will feel comfortable to directly contact with the researcher in the future. During the interviews, researcher stopped for a few seconds after each comment and question for additional comments and to give time to the participants to think.

Interview groups were formed according to the scores of three attitude scales. In this process, expert opinion was obtained. Two researchers - an assistant professor and a research assistant in that private university – studying in the field of assessment and evaluation expressed their ideas. They confirmed the statistical analysis on the formation of the three groups which is explained in detail under the attitude scales title (See section 3.2.1.4 for forming the interview groups).

Obtaining more than one homogeneous group out of an existing group was aimed with the purpose of providing maximum variation. It was intended to identify the common and different sides (Büyüköztürk, Kılıç, Akgün, Karadeniz, Demirel, 2008) of these three groups by conducting focus group interviews. While choosing the interview groups, a purposive sampling was conducted focusing on the scores that the participants obtained from the attitude scales as it was observed that the attitudes have an important role in the related literature (Guin & Trouche, 1998; Hennessy et al., 2001; Mitchelmore & Cavanagh, 2000).

The connection between maximum variation sampling and focus group interviews is explained by Patton (1990) as;

“Maximum variation sampling is the strategy of picking a small, homogeneous sample, the purpose of which is to describe some particular subgroup in-depth... Sampling for focus groups typically involves bringing together people of similar backgrounds and experiences to participate in a group interview about major issues that affect them.” (p. 235-236)

As Patton (1990) and Büyüköztürk et.al. (2008) stated, maximum variation sampling is a branch of purposeful sampling that serves the researcher to describe the problem widely. It was believed that the views of the groups which have different attitudes, was also going to differ (Guin & Trouche, 1998; Hennessy et al., 2001; Mitchelmore & Cavanagh, 2000). Therefore, three interview groups were formed instead of interviewing all of the participants as one single group.

#### **3.2.1.4 Attitude Scales**

Three attitude scales were conducted before and after the treatment in five weeks interval. The attitude scales are Learning Mathematics with Technology Attitude Scale (MTA), Mathematics Attitude Scale (MA), and The Technology Attitude Scale (TA).

MTA has been developed by Pierce, Stacey, and Barkatsas (2007). This scale was used to measure participants' attitude towards learning algebra with the GC CP. In the development phase of the scale, the data gathered from 6 schools were used. The research group constituted 350 students. By analyzing the previous similar

scales, the content and appearance validity were examined. Besides, by applying factor analysis, 7 items were omitted and five-factored design was defined. For the reliability analysis of the scale, Cronbach alpha coefficient was calculated. The Cronbach's Alpha for the five factors coefficients ranged from .65 to .89. MTA pre-test and post-test scores obtained from the participants of the current study were analyzed and for the reliability analysis of MTA, Cronbach alpha coefficient was calculated. The reliability coefficients of the pre-test and post-test scores obtained from the attitude scale on algebra and technology are 0.90 and 0.71, respectively.

MA has been developed by Duatepe and Çilesiz (1999). The research group which was used to develop the scale was comprised of 230 students who were taking Mathematics from the faculties of engineering, education, administrative sciences, and science at Middle East Technical University during the spring term in 1997-1998. Based on the findings, 6 items were excluded from the scale. As a result of the analysis, it was found out that the scale constituted 4 dimensions. Therefore, 13 items gathered in the first dimension were related to the interest and pleasure towards mathematics and 9 items in the second dimension were related to trust and fear. 8 items in the third dimension were regarding the significance of mathematics in daily and professional lives; 8 items in the last dimension were also regarding the interest, like and pleasure towards mathematics. For the validity of the scale, the correlation between the items and the dimension they were included was calculated. The lowest correlation value in the first dimension was .55, for the second dimension 0.62, for the third dimension 0.48 and for the fourth dimension 0.51. Furthermore, Cronbach Alpha coefficient regarding the scale developed was found as 0.96. MA pre-test and post-test scores obtained from the participants of the current study were analyzed and for the reliability analysis of MA, Cronbach Alpha coefficient was calculated. The reliability coefficients of the pre-test and post-test scores obtained from the attitude scale on mathematics are 0.96 and 0.94, respectively.

TA has been developed by Yavuz (2005). In the phase of scale development, in line with the resources that the researcher examined, a 5-point likert scale with 50 items was formed and it was applied to the 162 students chosen as the sample. As a

result of the analysis, a 5-factor scale with .87 reliability coefficient constituting 19 items was formed. The scale was named as “the state of not using technological equipments in education, the state of using technological equipments in education, the impacts of technology to the education, teaching how to use technological equipments evaluating the technological equipments”. In this study, for the reliability analysis of TA, Cronbach alpha coefficient was calculated and the reliability coefficient is found 0.86.

For the reliability analysis of the scales used in the study, Cronbach Alpha coefficient was calculated for each. In order to calculate the reliability coefficients, pre-test and post-test scores obtained from each attitude scale were analyzed. Correlation coefficients of the participants’ pre-test and post-test scores obtained from the three attitude scales were found above 0.70. The reliability coefficients are close with the original coefficients of the scales. Therefore, it was assumed that the correlation coefficients obtained from the 21 participants of this study are reliable.

The attitude scores of the participants were transformed into Z score. The students who participated in the research were classified into 3, which were high group, average group, and low group. The students whose Z scores obtained from each attitude scales were below -0.5 formed the low group since they had low attitude scores. The students whose attitude scores were medium-level (between -0.5 and +0.5) when compared to the other groups constituted the average group. In the high group, however, there were students who had +0.5 and the above Z score with high attitude (See Table 5).

Table 5. Attitude levels of the three interview groups

Group Number	Group Name	Attitude Level
1	Low group	Low ( $Z < - 0.5$ )
2	Average group	Medium ( $- 0.5 < Z < +0.5$ )
3	High group	High ( $Z > +0.5$ )

Interview groups were identified based on the post-test scores obtained from each attitude scale. In this identification, scores obtained from MTA was used as the basic score. According to their standardized MTA, MA and TA scores, participants

were grouped under three levels; the first group with lowest scores, second group with average scores and the third group with highest scores. Participants were grouped three times for each attitude scale separately. In other words, each student had three group numbers obtained from each of the three attitude scales.

Then, as MTA scores were used as the base, in other words as the reference scores, regarding the group number formed according to MTA, a student who had the common group number in at least one of the other two groups formed out of the other attitude scales was included to the related group (See Table 4). To explain further, one participant coded as number 5 (P5) was in the first group regarding her -2.10 score from MTA. She was also included in the first group according to her TA score. Therefore, she was accepted for the interview as the participant of the first group. As another example, P11 had the score -0.80 from MTA and was included to the second group. However, he had average scores from the other two scales which was the reason for the researcher to place him in the second group. As he was not included to the first group in at least one of the other two scales, he was not chosen as an interviewee for any of the groups. In Table 6, the sections presented with bold numbers indicate the corresponding group numbers for each participant. Those participants were chosen for the focus group interviews.

Table 6. Forming the interview groups according to the Z scores obtained from three attitude scales

Parti- cipant s	MTA (Z scores)	MTA (Group No)	MA (Z scores)	MA (Group No)	TA (Z scores)	TA (Grup No)
5	<b>-2.10</b>	<b>1</b>	-0.08	2	<b>-0.82</b>	<b>1</b>
2	<b>-1.54</b>	<b>1</b>	<b>-1.00</b>	<b>1</b>	<b>-0.72</b>	<b>1</b>
7	<b>-1.36</b>	<b>1</b>	-0.34	2	<b>-1.70</b>	<b>1</b>
11	-0.80	1	-0.48	2	0.30	2
15	-0.80	1	-0.34	2	0.35	2
1	<b>-0.62</b>	<b>1</b>	0.44	2	<b>-1.16</b>	<b>1</b>
9	-0.62	1	0.05	2	0.60	3
18	-0.62	1	0.71	3	0.16	2
17	<b>-0.43</b>	<b>2</b>	-1.00	1	<b>0.35</b>	<b>2</b>
19	<b>-0.25</b>	<b>2</b>	-1.27	1	<b>0.16</b>	<b>2</b>
8	0.12	2	-1.00	1	-1.74	1
10	<b>0.49</b>	<b>2</b>	<b>-0.48</b>	<b>2</b>	0.64	3
3	<b>0.68</b>	<b>3</b>	-0.34	2	<b>0.84</b>	<b>3</b>
16	<b>0.68</b>	<b>3</b>	<b>1.10</b>	<b>3</b>	<b>0.99</b>	<b>3</b>
21	<b>0.68</b>	<b>3</b>	<b>0.97</b>	<b>3</b>	0.06	2
6	1.05	3	-2.32	1	-2.33	1
12	<b>1.05</b>	<b>3</b>	0.44	2	<b>0.54</b>	<b>3</b>
13	<b>1.05</b>	<b>3</b>	<b>1.23</b>	<b>3</b>	<b>0.94</b>	<b>3</b>
14	<b>1.05</b>	<b>3</b>	<b>1.23</b>	<b>3</b>	<b>0.74</b>	<b>3</b>
20	<b>1.05</b>	<b>3</b>	<b>1.37</b>	<b>3</b>	<b>0.99</b>	<b>3</b>
4	<b>1.23</b>	<b>3</b>	<b>1.10</b>	<b>3</b>	<b>0.79</b>	<b>3</b>

Participants were selected for each interview group by the method explained above and the finalized list of the participants for each interview group is given below, in Table 7.

Table 7. The finalized version of the three interview groups

Group Number	Participant Number
1	P1, P2, P5, P7
2	P10, P17, P19
3	P3, P4, P16, P12, P13, P14, P20, P21

As seen in the Figure 2, the reasons why 0.5 Z score was used as criterion were to accommodate the attitude scores to the normal distribution by converting the



attitude scores into standard scores and to be able to divide this distribution into 3 groups which have equal attitude levels in itself considering the scores obtained from attitude scales. Moreover, as it can be seen in the figure, 0.5 Z score enables the whole area (99%) to be divided into 3 equal parts (33%).

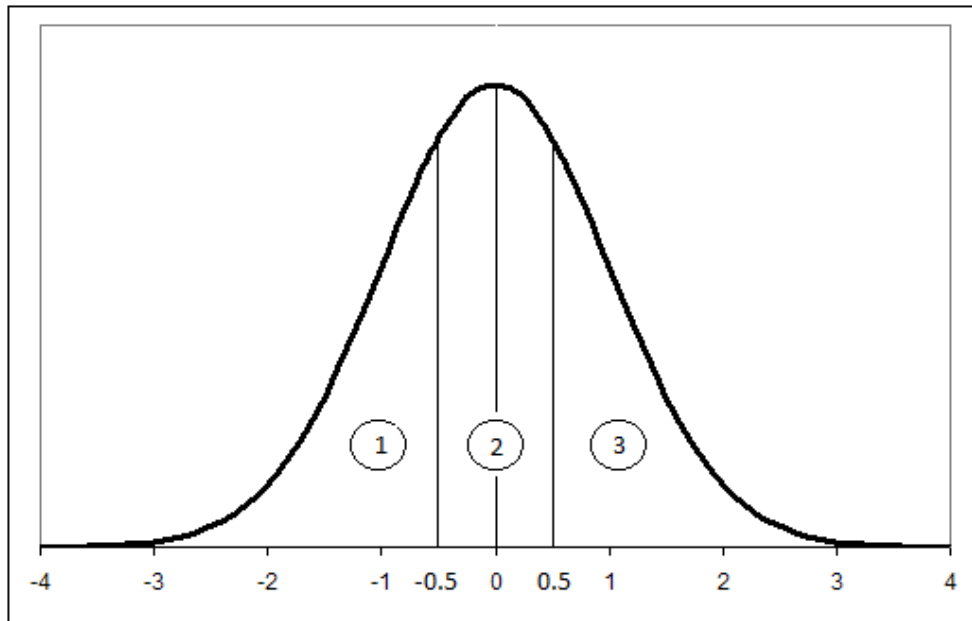


Figure 2. The indication of 0.5 Z score in normal distribution graphic

It can be seen from the attitude scale results that there is a significant difference between the three groups formed prior to the focus group interviews. The difference of the scores obtained from the attitude scales regarding the integration of mathematics with technology have an important role in learning and teaching of mathematics (Guin & Trouche, 1998; Hennessy et al., 2001; Mitchelmore & Cavanagh, 2000). Therefore, participants were classified in such a way to form the interview groups.

### 3.3 Data Analysis Procedure

Classroom observations, interviews, and open-ended questions were the main data sources of this study. Attitude scales were conducted in order to form the three interview groups. The sources of data in the current study and the data analysis

methods are summarized in Table 8. The methods in the analysis procedure mainly followed the steps recommended by Merriam (1998).

Table 8. Data sources and data analysis methods

Data Sources	Description	Number of Participants	Analysis Methods
Observation	4 weeks -16 course hours- video records	21	Content Analysis
Open-ended questions	5 open-ended questions	21	Content Analysis
Interview	3 focus group interviews	14	Content Analysis
Attitude Scales	3 attitude scales - Algebra and Technology - Technology - Mathematics	21	Statistical Analysis

The researcher took field notes about the course after each course session by focusing on participants' interaction with CP, statements of the participants about the process, and the difficulties they faced related with the CP, questions that participants asked to the researcher and to each other were also noted. During the instruction period, algebra learning area belonging to the grades 6, 7, and 8 was the main subject in the courses. The pedagogical use of the GC CP and their views about teaching with CP were also investigated. In addition, whether teaching the subject algebra through computer-assisted instruction contributes to their level of learning background was argued among the participants during the courses. Video records were watched repeatedly and compared with the observation notes to form other categories or to verify, refute the existing ones.

A questionnaire containing five open-ended questions was given to the participants after the last course of the instruction. Participants answered them in written format. Participants' answers were analyzed and expressions regarding the research question of this study were determined. The similar and different expressions were grouped. The interview questions were formed based on the answers to the open-ended questions.

Responses in the interviews were fully transcribed. The researcher assigned numbers from 1 to 21 to the participants of the study such as from P1 to P21. Among 21 participants, 14 participated to the group interviews. The numbers of the participants belonging to each interview group were written on top of the transcriptions. Then, interview video records were watched and listened several times for the complete transcription of the data. All of the conversations were quoted exactly. Interviews were transcribed in 30-second periods so as to access easily and quickly to any location of the dialogues later on.

After completing the transcribing process, the lines of the three transcriptions were enumerated. Then, transcriptions were read several times in order to group the statements of the participants. In the data coding procedure, firstly, the expressions in the interviews were expected to enter the categories formed from the five interview questions which are the advantages and disadvantages of using a GC in the teaching and learning of elementary level algebra, the obstacles and benefits of CP in mathematics courses, effect of CP on students' motivation, and the useful and useless features of the tool CP for mathematics education. When most of the statements could not be included in these groups, transcriptions were read again and related key words covering the main idea of each discussion part were written by matching the line numbers. These key words formed groups at the final revision.

In the first time, transcription of the low group was read in order to form categories. Table 9 gives the categories emerged in the first trial.

Table 9. The categories formed in the beginning of the analysis		
Main categories	Sub categories	
Advantages of CP	For teachers	
	For students	Elementary level
		Other grades
Disadvantages of CP	For teachers	
	For students	Elementary level
		Other grades

Then, transcriptions of the second and third groups were read and notes were taken to form categories. There were more specific comments in the second – average – and third – high – groups’ transcriptions that did not go under the categories in Table 7. For example, the statement that courses will be out of ordinary with the use of CP was suitable to enter all the sub categories under the “advantages” category. In addition, participants mentioned that CP should be used in specific parts of the mathematics courses such as warm up, application, and assessment. These comments which specifically pointed lesson design could not placed under a category. Researcher saw that there was a need for more specific categories. In addition, it was obvious that any comment was suitable to be defined as an advantage or disadvantage. Therefore, the two main categories, advantage and disadvantage, was omitted and sub categories became the categories as in Table 10.

Table 10. The changed categories during the analysis		
Main categories	Sub categories	
Teachers		Advantages
		Disadvantages
Students	Elementary level	Advantages
		Disadvantages
	Other grades	Advantages
		Disadvantages

The line numbers were noted near the related sub category and when there were lines that could not be placed under any categories, additional key words were listed under the category table such as comparison with paper-pencil, provides motivation, place of CP in a lesson, content of CP, physical features, use of CP. Then, after the analysis of the second group's interview was completed, there was no need to add any more key words in the analysis of the third group. All of the lines in the transcriptions of the three groups about CP and the classroom study, without ignoring any of them, were placed under a key word or a category in Table 11. In the last step, the common aspects among the key words were determined.

After analyzing the data obtained from the three focus group interviews, four weeks of classroom observations were analyzed. There was one video record for each course, 16 video records in total. In addition to the video records, the notes that the researcher took after every two-hour course were used as supportive data for the classroom observations. Every videotape was watched by noting down the situations listed below.

- Participants' interaction with the GC - CP.
- Behaviors and statements of the participants about the process and the GC CP.
- Active participation during the instruction.
- The difficulties that participants face related with the GC - CP.
- Role of the GC - CP in participants' learning.
- Questions that participants asked to the researcher and to each other.

The situations observed from the classroom studies were compared with the researchers' notes related to each course hour. Then, the data obtained from these notes were compared with the analysis of the interview data. The matching and differing points were investigated. Extra information gathered from the classroom observations and observation notes were added under the sub categories occurred from the interview analysis.

The written response of the participants to the questionnaire containing five open-ended questions was reviewed. Their statements were compared with the codes

formed in the analysis of the interviews and additional data was added under the related category. As a result, the titles of the categories and sub categories were finalized as in Table 11.

Table 11. The finalized categories at the end of the analysis

Main Categories	Sub categories	
CP as a personal tool	Personal thoughts in personal use of CP Physical features and technological equipment Functions, menus and content of CP	
CP as an educational tool	Effective use of CP in education Use of CP in elementary level  Suggested grades for CP use Comparison of CP with paper-pencil	Place of CP in a lesson plan Suggested subjects for CP use Elementary grade students' use of CP
Relationship between CP and motivation		

### 3.4 Validity and Reliability

In this study, one-shot case study design was conducted; therefore, validity and reliability of the study depends on case study principles. In addition, one-shot case study is a weak experimental design which carries the threats of the experimental design. As Yin (2003) stated, validity and reliability is the quality of any empirical research. There are some precautions taken to reduce the threats in this study.

Validity is simply explained as “the defensibility of the inferences researchers make from the data collected through the use of an instrument” (Fraenkel & Wallen, 1996, p. 153) which means that validity accurately relies on choosing valid

instruments that allow the researcher to gather, measure and give accurate data. According to Yin (2003), there are six sources to obtain data in a case study. Three of these sources, focus group interviews, classroom observations and questionnaire, are used in this study to minimize the threats and obtain construct validity. The use of multiple sources of evidence is called triangulation (Fraenkel & Wallen, 1996; Yin, 2003). Triangulation of the three qualitative data sources provided cross check between the data sources and enhanced the internal validity in this study.

In addition, internal validity; namely trustworthiness of the study is obtained by minimizing the threats mentioned by Fraenkel and Wallen (1996). Age and educational background of the participants in this study were close to each other. All of the participants attended to the data collection procedure. Only one participant, who planned to participate to the focus group interview with the high group, could not come to school at the time of the interview. Instruction period took place in participants' usual classrooms and in the CSE course that they had been attending for two semesters. They were familiar with the classroom environment and the course.

Researcher was the teacher of the participants in the CSE course for one educational year that the study was conducted. Therefore, they were also familiar with the researcher, which enabled the participants to express themselves comfortably during the data collection process. On the other hand, there was a possibility that the participants might not express their opinions truly owing to the fear of getting low grades from the CSE course or they might believe that the researcher wants to hear positive comments about CP. In order to reduce these risks, in the beginning of every course and in the interviews, participants were informed that they should feel comfortable to express their thoughts without the fear of making any mistakes and providing with incorrect information or ideas, as everything they utter to answer the questions were valuable for the outcomes. They were also convinced that they would not be graded according to the interviews, any of their comments were welcome about the instructional tool CP and their thoughts were valuable for mathematics education since they were the teachers of the future.

Considering the external validity in a qualitative study, there is a limited generalizability of the findings because the main aim is to obtain unique interpretation about a specific case (Cresswell, 1994). Cresswell (1994) mentions that although the uniqueness of case studies replicate the studies in other contexts, “statements about the researcher’s positions – the central assumptions, the selection of informants, the biases and values of the researcher – enhance the study’s chances of being replicated in another setting” (p. 159). As Cresswell (1994) and Yin (2003) suggested, the design of the research, data collection and analysis procedure, instruments, lesson plans, and findings of the current study were reported in detail so that the data collection procedure can be understood by another researcher without any step remaining unclear.

As Fraenkel and Wallen (1996) emphasizes, the obvious weakness of one-shot research design is that the researcher lacks the opportunity for controlling the variables. In this study, researcher could not compare the results obtained from the views of the participants, with another group or with the pre-testing of the views of the participants. There was a possibility that results might have been produced by other variables rather than the use of CP. To remedy this design, triangulation method was used. Following an instruction period of 5 weeks, participants were asked to answer a questionnaire and were interviewed in three groups. In addition to these three data sources, classroom observations of the instruction period were analyzed. Combining the results obtained from the three data sources, namely the triangulation of the data sources, increased the accuracy of the results.

### **3.5 Assumptions and Limitations**

#### **3.5.1 Assumptions**

The assumptions of the study are listed below.

1. All participants provided honest and accurate information during the interviews.
2. All participants answered the attitude scales accurately and honestly.



3. The researcher correctly recorded the data gathered from the interviews and classroom observations.

### **3.5.2 Limitations**

The limitations of the study are listed below.

1. The study was limited to 21 pre-service elementary school mathematics teachers at the private university in the 2009-2010 academic year.
2. Generalizability of the findings in another setting
3. The researcher effect occurred from the participant observer role of the researcher.

## **CHAPTER 4**

### **RESULTS**

Results revealed by qualitative analysis of the three main data sources – classroom observations, open-ended questions and interviews – were grouped under three main categories. Analysis of the observations and open-ended questions gathered from 21 participants were combined with the reported thoughts of 14 participants in the three interview groups.

Results were grouped under three main headings which are the use of CP as a personal tool, the use of CP as an educational tool and motivation. The three main categories and sub categories emerged in the analysis of the qualitative data is given in Figure 3.

Participants' views were categorized according to their aim in using the tool. According to their statements during the classroom observations and interviews, they categorized and rated CP as an educational tool in mathematics, a motivating tool when compared to other instructional materials, and a personal tool which they would like to use personally at home and out of the school, too.

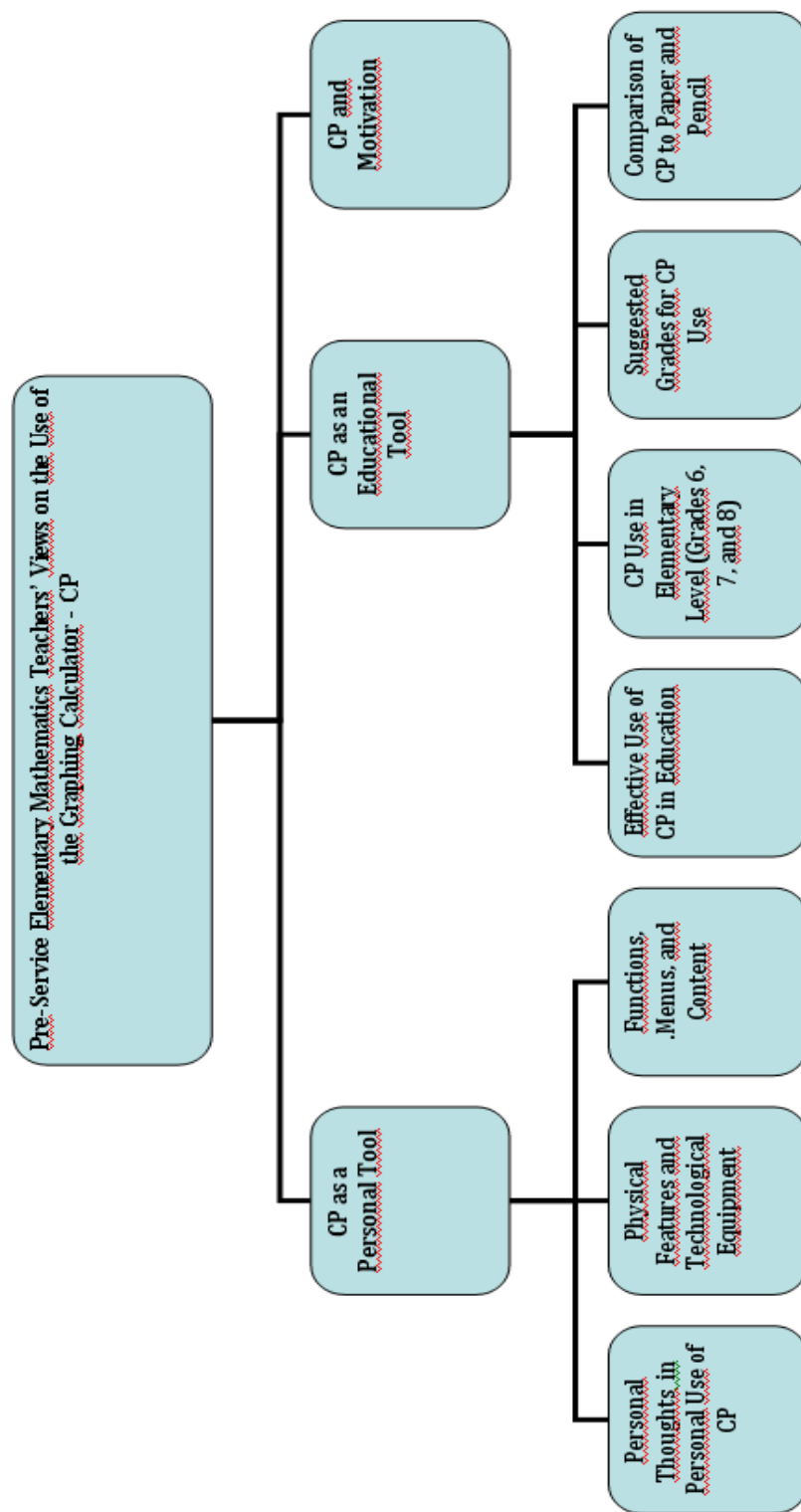


Figure 3. The categories and sub categories

In this chapter, there are three parts regarding the three main categories. In each section, results are reported with a table consisting the ideas, statements, and comments of the participants related with the category and the frequency values of these statements. Frequency values are given separately for each group (low, average, and high) and total frequency considering all of the participants is also presented in the tables. The expressions presented in the tables cover all the data gathered from classroom observations, questionnaire and focus group interviews. Whereas, frequency values refer to the data gathered from the interviews. Detailed descriptions of the statements and excerpts from the interviews follow the tables. Researchers' observations in the instruction period and participants' answers to the questionnaire are also reported in the related parts. In between, the three interview groups, which were classified according to their attitudes, were named as low, medium and high attitude groups. In some parts where the results were reported considering the three interview groups; low, average and high groups are expressed as the first, second and third groups, respectively.

In the last part of this chapter, the results were reviewed and reported again from a different point of view by comparing the participants' views according to their attitudes. The views of the participants having low, average and high attitudes were compared. The analysis of the attitude scales were only used in forming the interview groups. As the results of the attitude scales showed significance difference, views of the participants differing in terms of their attitude were considered important to be compared.

Participants' views on personal use pointed the personal experiences while using CP, the tool's technical equipments and functions of the menus. For the educational use, considering mathematics teachers' and students' benefits, participants referred to the appropriate use of CP under the headings of effective use of CP, appropriate grades for the use of the tool and comparison of CP with paper and pencil. In the last heading, relationship between the GC CP and motivation takes place.

Four of the menus (main menu, graphs and tables, e-activity, and geometry) of CP were frequently used during the instruction process. In order to provide the reader conceptual understanding of the results, a brief explanation related to each menu was given in methodology chapter.

#### 4.1 CP as a Personal Tool

The analysis of the data gathered from the 21 participants of this study revealed a category related with the personal use of CP. This category has three sub-categories which are personal thoughts in personal use of CP, physical features and technological equipment, and functions, menus and content of CP. These sub categories are reported in this section under three separate titles, respectively.

##### 4.1.1. Personal Use of CP

Participants' ideas in terms of the sub category, personal use of CP is presented in this section (See Table 12).

Table 12. The distribution of the low, average and high group participants' views on the sub category, personal use of CP

<b>Expressions</b>	<b>Low (n=4)</b>	<b>Average (n=3)</b>	<b>High (n=7)</b>	<b>Total (n=14)</b>
<b>Personal Use</b>	<b>f</b>	<b>f</b>	<b>f</b>	<b>f</b>
1. CP is easy to learn and use	4	-	6	10
2. I would like to learn all the menus of CP	3	-	5	8
3. The better one uses CP, the more he benefits	3	-	1	4
4. I am sufficient in using CP but I can be a better user if I use it for a long time	4	3	7	14
5. CP is necessary and important to a mathematician	-	-	4	4
6. CP is fun to use	2	1	1	4
7. CP took attention of the people around me	-	1	6	7

Considering the five-week instruction period, participants in the first and third groups think that learning how to use CP is easy. They considered the period since they have met with the tool and gave examples from the training period. In the training period which corresponds to the first week, some of the participants mentioned that the tool seemed very “strange” to them. By comparing the time of the interview and the training week, they mentioned that they have learned “too much” about the tool. Therefore, most of the participants expressed during the interviews and in the last weeks of the instruction period that using CP is easy. They told about their experiences from the tasks they worked on in classroom studies. In the interviews after mentioning their experiences regarding the first week, participants concluded that they feel more comfortable in using CP at the end of the five-week classroom studies. This was mentioned not only during the interviews but also at the end of the instruction period in the classroom when researcher asked the participants’ thoughts about the period, almost all of them defined themselves as an efficient users of CP. As in the script below, they expressed that using CP is not that hard as they thought when they first met the tool.

*“After learning, everything becomes easy.” (Group 1, Person No: 7, Page 3, Line 103)*

When P7 expressed that after the learning process there is no difficulty, P1 confirmed him. P20 gave an example to explain how he felt about the use of CP. He likened CP to touchpad cell phones, which almost every friend of his owns one of those cell phones. He mentioned that operating CP is as easy as operating those new technology cell phones.

*“Everything writes there already, we can explore from there.” (Group 1, Person No: 1, Page 1, Line 31)*

*“Everyone has a cell phone anyhow, it (CP) is very similar to a phone, and similar to a calculator. Its use was very easy; it was not hard for me.” (Group 3, Person No: 20, Page 3, Lines 106-107)*

In addition to the easy learning and using of the tool, some participants in the third group mentioned the practicality feature of the tool. The facility of CP of giving

immediate feedback was considered as practicality and participants mentioned this frequently through the classroom studies.

*“You say solve the equation, we immediately push action (command), inequalities (command), and solve (command), or write the equation and click exe (button). It (CP) has this kind of practical facilities.” (Group 3, Person No: 4, Page 1, Lines 29,31)*

All the participants in the three groups expressed that they consider themselves sufficient in terms of using the four menus that they have used in the instruction period. Whereas, they all think that they are not sufficient when they consider all the facilities and menus of CP. Moreover, participants showed an interest on using CP professionally. Through the last courses, they mentioned that their familiarity and experiences with the tool make them interested in all the functions of the tool. They also stated that their interest leaded them to learn all the menus and every function of each menu in CP. In all the three groups, participants expressed their eagerness on learning CP as the following scripts.

*“We could have learned other things. There are a lot of menus, we used only e-activity, main menu and graphs. That would be better if we have learned more.” (Group 1, Person No: 5, Page 1, Lines 36-38)*

*“I would really like to know how to use all the menus in this tool professionally.” (Group 3, Person No: 3, Page 7, Lines 222-223)*

All the participants in the three groups stated that they will be able to use CP more effectively if they use it longer than the five-week instruction period. During the four weeks of the instruction period, participants used CP in elementary level algebra subjects. By mentioning this, they also stated that their eagerness to use a GC while working on the mathematical subjects at university level increased.

*“As we studied 6<sup>th</sup>, 7<sup>th</sup> and 8<sup>th</sup> grade algebra... I mean we learned how to do things we already know in different ways. If we had learnt how to use CP in higher level subjects for example like linear algebra, trigonometry, that would be better.” (Group 1, Person No: 2, Page 2, Lines 79-82)*

*“ (Five weeks) Not enough for me. Because five weeks was a short period of time but we learned the basic things. We are able to do them, for example we were able to solve the equations.” (Group 2, Person No: 17, Page 6, Lines 191-192)*

P20 argued that they would be using the tool with all its features if they had been dealing with it for the whole course time, through the two semesters which P3 and P14 also confirmed.

In the observations and interviews, most of the participants expressed that they tried to make calculations with CP and tried to explore the other menus of the tool different than the menus that they had experienced in the instruction period. On the other hand, a common thought expressed in the three groups was that they needed assistance to use the menus when it was their first time. This was also observed during the instruction process that students were not able to use the menus effectively which were not thought by a teacher. Some of the participants gave examples from their experiences while working on subjects other than elementary level algebra. They mentioned the difficulties they faced when there was no one guiding them to find the needed functions.

*“Actually I can not use it totally, so as in the classroom. For example we were solving an equation, we click there, click solve. If you do not show, we might find by searching but we can not find immediately.” (Group 3, Person No: 16, Page 7, Lines 243-245)*

*“I tried to solve integral, it solved some of them and did not solve some others. Also, in graphs I tried logarithmic graphs but I could not.” (Group 2, Person No: 17, Page 1, Lines 9-10)*

After the researcher reminded them that she had told them to try using the menus they did not know in their free times, P3, P14, and P16 mentioned the need for an assistance for the unknown menus as:

*“We tried, but you come to a point that you can not even log out of the current page (window)... If we have learned those in the lesson, we might be able to do the rest, if we had time. That would be great.” (Group 3, Person No: 3, Page 7, Lines 227, 238)*

*“We learned this for 6<sup>th</sup>, 7<sup>th</sup> and 8<sup>th</sup> levels. There are a lot of menus we used... But we did not learn most of them. I turned it on at home; I did not understand anything. We should have some basic knowledge about that (menu).” (Group 3, Person No: 14, Page 18, Lines 667-669)*



Regarding the benefits, obstacles, features and the menus of CP that they had experienced in the five weeks of the classroom studies, participants expressed the meaning of CP for themselves and for people dealing with mathematics. They exemplified the role of CP for mathematics teachers in two ways such as for a mathematician being helpful in professional development and for a teacher in task preparation. In the third group, four participants mentioned the importance of CP for mathematicians as follows:

*“It (CP) is beneficial for the one who use it with all of its functions and who is dealing with this work. It saves time, too.” (Group 3, Person No: 4, Page 20, Lines 751-752)*

*“I think, when we think hard on CP, I mean when we understand it more, use it more practically, as a mathematician especially in graphs, functions and etc, it could become a part of our lives. In my opinion, if we work on it some more, improve ourselves more, we can benefit from it.” (Group 3, Person No: 3, Page 2, Lines 39-42)*

Considering the easy use of CP, willing to learn all the functions of it and considering CP as tool that has a crucial role for a mathematician, participants mentioned that the better one uses CP, the more he benefits.

*“After having learned, they (users) can benefit more from this. I mean we can not benefit totally because we only use (limited with) as far as we know.” (Group 1, Person No: 1, Page 5, Lines 209-210)*

*“When we have learned how to use it, we understand that it is very beneficial.” (Group 3, Person No: 20, Page 21, Line 793)*

P1 and P2 from the first group mentioned that using CP was enjoyable for them. Similarly, this was also frequently observed during the instructions that P1 used CP even in the breaks and asked several questions to the researcher about every menu of the tool.

Like P1 and P2, P16 was also very interested and eager to learn CP with all its functions; did not give up at the times she could not operate the calculator. P16 was a participant selected to be in the third group of the focus group interviews but did not attend the interview. She expressed her ideas about CP in the classroom with the following expression taken from the video records:

*“Since I started university, it is the first time I feel that I am in a department dealing with mathematics.”*

Third group has the maximum interest in the use of CP. As this was the result of the analysis of the attitude scales, the interest of the 8 participants in the third group was also observed in the classroom studies, seen in the answers to the questionnaire and reflected in the group interview.

In addition to their personal interest on the tool, some participants in the second and in the third groups mentioned the interest of the people around them to CP. In the second group, P17 expressed that his friends found CP different for the reason that the tool covers almost all of the mathematical subjects. In the third group 6 participants pointed to people’s views around them. P16 mentioned her brother’s response on CP.

*“I looked at the things we did not do in class. There was finance, statistics. I do not understand most of them; I do not know any statistics. My brother is a student in Hacettepe, he has statistics courses, I showed him. He told me something about it. It (CP) took so much of his interest, too.” (Group 3, Person No: 16, Page 7, Lines 231-233)*

P21 from the third group mentioned his friends’ interest on the tool by expressed that a friend of his who was a student in economy wanted to buy a CP for himself when P21 introduced CP to him. Another participant, P4, has been giving private lessons on mathematics, one to one and as a group, to the students who are preparing for university entrance exam. He explained his experiences with his students as in the following script.

*“My student said, ‘teacher, give me half an hour.’ He solved all the questions in mathematics-2 part of the preparatory exam of LYS (national student selection examination) with this (CP). All of the questions. There is no question that he could not solve... The general concept was derivatives, integral, trigonometry, sequences, series.” (Group 3, Person No: 4, Pages 11-12, Lines 413-414, 416, 418)*

In the third group, 5 participants also stated that the people around them whom they do not know also show interest to the tool, in the school bus and outside.

There was not enough information in views of the second group about the interest on CP from outside.

Despite the facilities of CP such as practicality, broad content, enjoyable and usefulness; three participants in the third group stated a disadvantage that CP might cause which is the tool might condition the users for ready-made answers.

*“We might be getting lazy but it (CP) is needed.” (Group 3, Person No: 20, Page 20, Line 746)*

*“Generally, it is good. Actually, I thought about it in my free times. It is a very good tool in terms of its use. But it gives a little bit laziness in terms of calculations, presents ready made information.” (Group 3, Person No: 4, Page 1, Lines 10-12)*

#### **4.1.2 Physical Features and Technological Equipment**

Participants’ ideas in terms of the sub category, physical features and technological equipment of CP is presented in this section (See Table 13).

Table 13. The distribution of the low, average and high group participants' views on the sub category, physical features and technological equipment of CP

<b>Physical Features and Technological Equipment</b>	<b>Low (n=4)</b>	<b>Average (n=3)</b>	<b>High (n=7)</b>	<b>Total (n=14)</b>
1. Touchpad is an advantage	1	-	-	1
2. Using stylus sometimes causes problems	1	1	2	4
3. CP can connect to internet	3	1	6	10
4. CP can have a colorful cover	2	-	3	5
5. Screen can be lightened	3	-	5	8
6. The size of CP can be smaller	2	0	4	6
7. Screen dimensions are appropriate or can be enlarged	3	1	4	8
8. CP can have sliding keypad	3	1	5	9
9. Screen can be displayed colorfully	1	-	4	5
10. CP can be equipped with a video camera	1	-	1	2
11. A memory card can be added	0	-	1	1
12. CP and computer connection is an advantage for teachers and students	0	-	2	2
13. CP can also work with a battery	-	-	4	4
14. CP can be voiced to learn a foreign language	-	-	1	1

Participants were observed as comfortable with the physical features of CP during the courses. They got used to the sizes of the tool in a short time, they were able to use the stylus (the pen of the tool to operate the touchpad screen) in right directions. During the observations, in their answers to the questionnaire and in the interviews, the common response was that they had no complains of the existing technological equipment of the tool. Thus, they gave some suggestions to improve it.

Participants in the first group did not mention any problems in the use of CP at all. One participant in the first group considered touchpad as an advantage. Although only one participant mentioned this, during the observations most of the participants were impressed with the touchpad feature of the tool and they stated that

it was a “charming” advantage of the tool which encouraged them to use the tool. On the other hand, three participants stated that stylus sometimes causes problems. One of them was P1 who sometimes had problems with stylus in some courses. This problem was solved with the calibration setting of the tool. Other participants gave examples about how they faced some problems occurred from the stylus as in the following excerpts.

*“Sometimes we click, it reacts after more than one time...I had this sometimes, I mean a few times.” (Group 2, Person No: 10, Page 3, Lines 72, 74)*

*“While using this pen, it sometimes works slowly, it causes a problem sometimes. When my hand gains speed, this time pen can not catch me up. I click, it can not catch me. It sometimes halts.” (Group 3, Person No: 12, Page 4, Lines 108-110)*

Another function that participants suggested during the observation period was approaching to internet via CP. In the first group, 3 participants suggested the connection of the CP to internet for educational aims such as students can download questions or assignments that teacher have put on a website.

*“It certainly should be connected to internet. One can download question from there, and solve the questions on it.” (Group 1, Person No: 1, Page 7, Lines 289-290)*

In the second group, only 1 participant mentioned internet connection. Whereas, in the third group, 6 out of 7 participants wished CP would connect to the internet. During the instruction process, internet connection was frequently subject of discussion that almost all of the participants suggested.

In the third group, two participants considered the connection of CP to computer as an advantage for teachers and students. P20 wondered sending files from CP to computer when the memory of CP is full. He was impressed with this connection. He asked about this connection and file transfer in the classroom during the instructions and he stated that this is a very useful facility for students. He asked about this again in the group interview.

For the physical features of CP, 2 participants from the first group and 3 participants from the third group suggested that the tool could be in different colors. The reason was that, P14 imagined two tools; one of them having different level of menus in it, the other one for elementary grade and the other for secondary grade. Therefore, he suggested the color also differ as the content. P14 from group three expressed her reason for a colorful CP as:

*“In my opinion, it should be in different colors. Both elementary and secondary grades should not use the same color... Colorful covers will be absolutely interesting.” (Group 3, Person No: 14, Page 6, 17, Lines 203-204, 641)*

In the first and third groups, 3 and 5 participants respectively, mentioned the illumination of the screen. They expressed that the light of the screen is too low to use the tool in the evenings.

*“If it can be illuminated, it will be easier to study in the evenings.” (Group 1, Person No: 7, Page 3, Line 110)*

*“It should be illuminated to use at nights.” (Group 3, Person No: 3, Page 17, Line 643)*

In the first group, 2 participants thought that CP should be smaller in dimension but wider in the screen. They suggested that screen should show more images at once. Besides, P5 thinks that dimensions of the tool should be smaller when the tool is considered as a calculator, whereas P1 and P7 prefer the present dimensions of the tool because it has a wide screen.

Another suggestion about the technological equipment of the tool was, as 1 participant suggested, the images on the screen turn when the tool is turned.

*“Also, when we hold it like this (by tilting it to left), screen can turn. It can be used like this. Screen will become bigger and wider.” (Group 1, Person No: 5, Page 7, Lines 302-303)*

In the first group, P1, P2 and P7 suggested that keyboard of the tool can be movable and sliding that it can be used when it is needed. Whereas, in the second group, P19 suggested to remove the keyboard and to enlarge the screen.

*“For the dimensions, screen can be enlarged a little more. If there will be a new model, I think these buttons are unnecessary, because there is a touchpad keyboard which does the same things.” (Group 2, Person No: 19, Page 9, Lines 300-303)*

Third group reached the solution of keypad being portable by expressing two opposite ideas. In the third group, 4 participants suggested that CP can be smaller in dimension but the screen dimensions will remain the same. They suggested reducing the tool to a pocket size by removing the keypad buttons.

*“If touchpad screen will be more practical in use, there will not be any need for the buttons below. It can be just the screen... For the screen this size is ideal actually. Not too large, not too small. Things can be seen quite clearly.” (Group 3, Person No: 4, Page 17, Lines 602, 606-607)*

For the suggestion of removing the keypad buttons on the CP, three participants (P3, P4 and P20) expressed the reason of more functional keyboard appears on the screen.

*“Below the blue buttons are needless.” (Group 3, Person No: 20, Page 17, Line 608)*

In addition to the keyboard appears on the calculator that has buttons related to basic calculation as in a regular calculator, there is a more functional keyboard on the touchpad screen. In the third group, P4 suggested the touchpad keyboard that appears on the screen be enlarged in order to prevent wrong clicks.

*“For the appearance of the screen, keyboard could have been bigger. For example when I click plus, generally the thing I see on the screen is the word ans. ‘Ans’ button is under plus button, when you click plus you click ans. I check the calculations, they are full of ans.” (Group 3, Person No: 4, Page 4, Lines 112-115)*

P14 from group three defended an opposite idea to others by stating that the tool being only touchpad is not appropriate for elementary grade students instead, buttons and keyboard is better for them. P21 confirmed this idea.

*“We handled this tool for elementary grades. You showed us things that they will deal with. According to me, touchpad is not an advantage for 6<sup>th</sup> grade. A person in our age may use this comfortably, we even had difficulties. Rather than touchpad, normal keyboard makes more sense.” (Group 3, Person No: 14, Page 6, Lines 193-196)*

P4 and P20 implied that it is about getting used to touchpad. They believed that the more experience one have on the use of CP, the more he gets used to the touchpad key board. Some of them mentioned that CP is like the new technology touchpad call phones that almost everyone owns one. Therefore, most of the participants believed that operating the touchpad screen would not cause any problems in long term.

*“You will learn by using and using.” (Group 3, Person No: 20, Page 17, Line 622)*

*“I can give an example about myself. I was using my normal call phone. After using i-phone I got used to I-phone and I can not use normal cell phone now. For example, I had so much difficulty while text messaging with i-phone. This is a habit. If you use it, you also get used to it.” (Group 3, Person No: 4, Page 17, Lines 625-630)*

*“You can get used to it.” (Group 3, Person No: 20, Page 17, Line 631)*

The other feature suggested to be included in CP was colorful screen. It was suggested by 1 participant in group one and 4 participants in group three regarding that the tool can be interesting and take more attention with a colorful screen.

There were other technological equipments that participants suggested to add to CP. From group one and three, 1 participant from each, suggested that camera can be added to CP. P20 from group three suggested the camera in order to record the teacher and lesson. P21 from group three suggested memory card to be added to CP. P21 suggested a program download to CP, which enables the teacher to control students' CP works on the teacher's computer. P17 in the first group has a concern about the technological part of the tool that it can suddenly turn off as it works with dry cells.

*“It is already an electronic tool, although it is tuned off the screen you are working on comes up again, but it might brake suddenly or its batteries may die.” (Group 1, Person No: 17, Page 2, Lines 44-45)*

In the third group, 4 participants suggested batteries as an alternative to dry cells. Some excerpts about using batteries are given below.



*“We use this by dry cells. There can be both dry cells and charge... I do not know if it can be, but both of them, you can either use the dry cells or the charge.” (Group 3, Person No: 3, Page 6, Lines 188-189)*

*“As I have mentioned in the beginning, I do not approve dry cells. Every one uses chargeable tools now. This can also be chargeable. Moreover, dry cells fill space.” (Group 3, Person No: 20, Page 18, Lines 646-647, 649)*

P4 and P20 also suggested CP be chargeable with usb connection. P3 suggested the tool be appropriate for the use with both dry cells and battery. P4 from group three suggested the tool speak out with a voice facility if it will contain dictionary in the new models.

#### **4.1.3. Functions, Menus, and Content**

Participants’ ideas in terms of the sub category functions, menus and content of CP is presented in this section (See Table 14).

Table 14. The distribution of the low, average and high group participants' views on the sub category, functions, menus, and content of CP

<b>Expressions</b>	<b>Low (n=4)</b>	<b>Average (n=3)</b>	<b>High (n=7)</b>	<b>Total (n=14)</b>
<b>Functions, Menus, and Content</b>	<b>f</b>	<b>f</b>	<b>f</b>	<b>f</b>
1. The content of CP is broad and sufficient in terms of mathematics	3	-	5	8
2. It provides ease in calculation	3	-	-	3
3. E-activity is a frequently used and useful menu	1	2	7	10
4. E-activity should be revised in order to provide ease in usage	-	2	-	2
5. Geometry menu is interesting for me	1	1	1	3
6. CP is a beneficial tool as it provides calculation, solving equations and graphing	4	2	7	13
7. The menu Spreadsheet is hard to understand and use	2	-	-	2
8. CP can show calculation steps	1	-	7	8
9. Menus can be separated according to grades and be downloaded when needed	-	-	3	3
10. Other subjects like chemistry and physics can be added to the content of CP.	-	-	4	4
11. For ease of use, the language should be totally Turkish.	-	-	2	2
12. Foreign language menu can be added.	-	-	5	5

All the participants in the first group regarded the menus of CP as having full content for all levels of mathematical subjects. In addition, 5 participants from the third group emphasized the usefulness of CP in university level especially in the mathematical courses that they will take at their second and third year. They expressed their ideas on the content of CP as follows.

*“In the further semesters we will learn double, triple integrals. This (CP) can be beneficial in those subjects.” (Group 3, Person No: 21, Page 12, Lines 421-422)*

*“We met with this (CP) in university level, started to use it at university. We will have physics course, too. I think, we should be able to use it in physics, too.” (Group 3, Person No: 3, Page 18, Lines 670-671)*

On the other hand, some participants expressed that they do not have any idea whether the tool is sufficient for all the subjects of mathematics in all grades because of the reason that they have only learned to make calculations on elementary level algebra.

*“We did not try to learn the things it can not do. You showed us things that it can do.” (Group 1, Person No: 2, Page 3, Lines 112-113)*

There was not enough information about views of the second group in terms of the content of CP whether it is broad or not.

All of the participants in the first group mentioned the easy use of the tool. They stated that they feel comfortable while using CP because it provides computational easiness such as immediate calculations and sketching; assists the user in operating the menus easily. They gave some specific reasons as:

*“We can solve everything easier, when we write an equation it finds directly everything about it.” (Group 1, Person No: 5, Page 1, Lines 21-22)*

*“Especially in graphs, you do not deal with any point or any part of it.” (Group 1, Person No: 1, Page 1, Line 23)*

*“We push some buttons at most.” (Group 1, Person No: 7, Page 1, Line 24)*

In the second group, 2 participants stated several reasons for considering CP as a beneficial and useful tool by giving examples from their experiences. In addition to the graphing facility which was mentioned in the first group, participants of the second group also emphasized solving equations with CP. In the graphics and tables menu, in the tasks related with equations participants realized that CP provides several functions such as sketching the graph of an equation by dragging the equation to the coordinate axis window, showing the variable table of a given equation, and the graph changes when the coefficients of an equation is changed. P17 exemplifies these functions by referring to the algebraic tasks as follows.

*“In some equations, like  $x$  equals to  $y$  equations, we were able to see the variables of the equations in the table, and also we hold the graphs and put it inside, it was so much fun.” (Group 2, Person No: 17, Page 3, Lines 64-65)*

For the numerical calculations in the main menu and solving equations in graphics and tables menu, the idea that CP should show the steps of the calculations was mentioned by 1 and 7 participants from the first and the third group, respectively.

*“This tool directly solves the question, skips the steps, gives the result directly. For example, when we solve a question we do step by step, I mean we do the summing, subtracting. This (CP) makes us solve the question directly.” (Group 1, Person No: 5, Page 3, Lines 130-132)*

*“In the subject equations, there should be the steps.” (Group 3, Person No: 21, Page 16, Line 579)*

P4 from the third group explained the need of seeing the solution steps by mentioning factorization as an example as in the following script.

*“For example we do factorization, we say the equation  $x$  square minus  $x$  is minus two; factorize it. We write it here (CP), okay, we push exe it is factorized, no logic. What is it? How do we factorize?” (Group 3, Person No: 4, Page 2, Lines 56-57)*

Participants criticized CP in terms of its menus. Firstly, among the menus of CP, e-activity was considered as an important and useful menu for the fact that in e-activity there is a platform to bring up all the needed menus and functions of CP together. When participants was asked the question of “what would you change to make a better GC”, P1 expressed her idea as:

*“E-activity should be included (in a new tool), as everything can be done by using it.” (Group 1, Person No: 1, Page 7, Line 284)*

P10 and P19 mentioned the menu e-activity as the key menu for the reason that the menu enables the user to combine other necessary menus and bring up the functions together. Similarly, all of the participants from the third group consider the menu e-activity as a menu includes all the other menus in CP, letting to transform equations into graphs; therefore very useful. Participants expressed their views about the facilities of e-activity menu as in the following excerpts:

*“Everything.” (Group 3, Person No: 20, Page 7, Line 255)*

*“We are able to open two or three pages at the same time which is very good-one for the equation, another for the graph. In the same page you can pass to the one you want to.” (Group 3, Person No: 4, Page 7, Lines 256-257)*

On the other hand, despite mentioning the facilities that e-activity provides, 1 out of 14 participants attended to the interviews expressed that she could not use e-activity comfortably and effectively.

*“If I am to talk about my experiences, some menus seemed complicated to me. I was having difficulty especially in e-activity, it was too complicated for me... It seemed very complicated to me. As we do lots of things there, equations etc, I get confused.” (Group 2, Person No: 19, Page 5, Lines 149-150, 153-154)*

As a solution, P17 gave a suggestion to make the menu e-activity more understandable and be operated easier. As P17 considered e-activity menu having so many functions, she suggested that the menu might include sub titles and be divided into some sub menus.

Secondly, geometry menu was considered as the other menu which has several functions to study most of the geometrical subjects. Participants expressed that the visual screen where the geometrical figures are constructed, takes attention, enhances interest to work on geometry; therefore facilitates learning. Specifically, P3, P5 and P19 mentioned geometry menu as useful, understandable and interesting.

*“In my opinion, I would use CP mostly in geometry... For the figures, visualization, and taking students’ attention more in the lesson, I liked geometry menu more. It can make students more active.” (Group 3, Person No: 3, Page 13, Lines 455-458)*

All the participants in the first group referred to the graphing and sketching abilities of CP which allows for immediate and accurate construction of geometrical figures. For these reasons, they considered geometry menu useful and beneficial.

*“It (CP) provided convenience mostly in graphs. Because it sketches immediately.” (Group 1, Person No: 5, Page 2, Line 49)*

Lastly, in the interviews, participants complained about operating the spreadsheet menu. Also in the classroom studies, participants faced obstacles in the

course when they were conducting a task on spreadsheet menu. P1 from the first group expressed that she could not use the menu spreadsheet in the classroom exercises; therefore could not understand the aim of it. P7 confirmed her view.

*“Spreadsheet can be changed to be seen totally. Half of it is there, half of it is here, you can not see the whole. Then, you can not do anything.” (Group 1, Person No: 1, Page 7, Lines 288-289)*

Considering all of the menus, functions and CP as an educational tool there were suggestions to improve CP. In the third group, P14 and P20 suggested that CP can be separated according to the curriculum for each level.

*“I would divide CP into two. You will say how. I think there are too hard subjects in it, also too simple subjects. We can do every kind of calculation. For example if we give this to an elementary grade student, how will he understand integral, derivative, limit, algebra?” (Group 3, Person No: 20, Page 4, Lines 127-129)*

P4 rejected this idea by saying that as a teacher they can use CP in the subjects and specific parts of the lesson which they consider appropriate. He imagined CP as a tool having a download function and the user could select and download a program when needed. P4 explained his suggestion as follows:

*“It can be produced as a tool. For example, there can be programs for each level in its own web site to be downloaded as it has usb connection... For example you can download the program for sixth grades.” (Group 3, Person No: 4, Page 4, Lines 132-133, 135)*

In contrast to P20, P3 states that she prefers the tool originally with all its menus included in it and explains the reason of her idea as:

*“In my opinion, it is very good to include all the subjects in it, because you never know which of them you will need anytime.” (Group 3, Person No: 3, Page 6, Line 183)*

Another idea that came up from the participants during the interviews was that they would prefer to use CP in other courses. The reason that CP is a mathematical tool, serves visualization to the user, includes mathematical menus that can be used in other science areas; participants chose to use the tool in physics and

chemistry, too. Therefore, subjects, other than mathematics, were recommended to be added to CP by 4 of the participants in the third group.

*“Programs of science and social sciences can be downloaded to these tools. They (elementary grade students) have three basic courses. This can be efficient in history courses, too. Instead of reading from the book, it can be more interesting to see things here (CP).” (Group 3, Person No: 21, Page 13, Lines 486-488)*

*“The content of it is good. But as P21 said, physics and chemistry can be added. They are also quantitative.” (Group 3, Person No: 20, Page 18, Lines 664-665)*

*“We met with this (CP) in university level, started to use it at university. We will have physics course, too. I think, we should be able to use it in physics, too.” (Group 3, Person No: 3, Page 18, Lines 670-671)*

*“These courses are everywhere, in elementary school, high school. These include graphs, too.” (Group 3, Person No: 20, Page 18, Line 672)*

Other than the courses those includes mathematics, 4 participants in the third group suggested the tool include a menu for foreign languages for their personal development as a teacher. P3, P14, P20 and P21 think that with the help of a language menu, they can learn technical terms about teaching and mathematics in English or in another language. A foreign language menu was suggested to be one of the downloadable programs as the participants mentioned before.

Apart from its content, in the third group, 5 participants mentioned the language of the tool. They complained about English written menus and recommended the tool be in Turkish to be more understandable and for efficient use.

*“There is one thing very important. We are used to mathematics, as we are a student in mathematics. This tool is half Turkish and half English now. If it will be used in lower levels this should be totally explained in our language.”*

#### **4.2 CP as an Educational Tool**

Educational use of CP is classified into four main titles; effective use of CP, use of CP in elementary level, appropriate grades for CP use and comparison of CP to paper and pencil.

#### 4.2.1 Effective Use of CP in Education

Participants' ideas in terms of the sub category, effective use of CP in education is presented this section (See Table 15).

Table 15. The distribution of the low, average and high group participants' views on the category, effective use of CP in education

<b>Expressions</b>	<b>Low (n=4)</b>	<b>Average (n=3)</b>	<b>High (n=7)</b>	<b>Total (n=14)</b>
<b>Effective use of CP in Education</b>	<b>f</b>	<b>f</b>	<b>f</b>	<b>f</b>
1. CP is sufficient in terms of all algebraic subjects in elementary level	3	-	-	3
2. CP helped me like algebra	3	1	2	6
3. CP helps you save time	2	3	2	7
4. Visualization facility of CP is an advantage in learning mathematics	1	3	7	11
5. Multiple representations facility of CP is an advantage for learning mathematics	1	-	4	5
6. I would use CP in classroom when I am a teacher	3	3	7	13
7. Teachers should be capable of using CP	-	-	7	7
8. Crowded classes would cause problem	1	1	2	4
9. Courses will be out of ordinary with the use of CP	-	-	1	1
10. Use of CP would lead students to research based learning	-	-	3	3

Participants mentioned their views on CP as an educational tool considering the algebra instruction period. All of the pre-service teachers participated to the study mentioned that CP had a broad content for elementary level algebra education. They mentioned that they liked mathematics, especially algebra, when they studied on algebraic tasks with CP. Some participants mentioned the change in their views about mathematics, particularly algebra. Participants reflected their ideas by explaining their feelings prior to meeting CP about mathematics.



*“I normally don’t like mathematics I even hate it. I don’t even want to attend the courses. I don’t understand much, either. But this tool itself make the calculations, you see everything. As it is enjoyable, I liked it. It is like I feel more self-confident.” (Group 1, Person No: 1, Page 2, Line 63-66)*

*“I was not able to solve problems. I put them into this (CP) and it immediately solved.” (Group 1, Person No: 1, Page 2, Line 75-77)*

*“It makes you like it (mathematics).” (Group 1, Person No: 5, Page 2, Line 67)*

With the support of their experiences, all of the participants expressed that the use of CP would positively affect students in learning mathematics and CP will make the students like the lesson same as the way they felt.

*“It will make the students like mathematics.” (Group 3, Person No: 14, Page 21, Line 763)*

*“For a student... There is no such thing that all students like mathematics. Point of view of a student who does not like mathematics might change. Firstly, the course will be out of ordinary. Secondly, as P20 said we will be able to verify ourselves. Yes, maybe we can do calculations from our memory but when we see that here (CP) it is a concrete example of it.” (Group 3, Person No: 3, Page 21, Lines 780-784)*

In addition to capturing participants’ interest on mathematics, CP seemed like a time saver machine for participants. By referring to the classroom studies, they expressed that time was saved in the learning and teaching period by leaving the calculations to CP. Therefore, they mentioned that students would be able to work on more activities and tasks in the remaining times.

*“Learning will be faster.” (Group 1, Person No: 7, Page 3, Line 91)*

*“Less time is needed when doing exercise. Time spent will be less. ” (Group 1, Person No: 7, Page 3, Line 91)*

In addition to the comments on the time saving role of CP mentioned in the first group, 1 participant in the second group reflected his idea by referring GCs’ role of verification. In the third group, P4 associated multiple representation facility of the tool with the time saved during the courses. After the other participants’ comments about the tool that it gives opportunity for multiple representations, P4

mentioned that this also saved time spent by producing those representations by hand.

*“CP will show them (students) where they made mistakes. They might not need a teacher... They will actually but they might understand without asking a question. In that point, time will be saved. Because, rather than intervening to 40 students, intervening only one student who does not understand is better for me. I will solve more examples.” (Group 2, Person No: 17, Page 5, Lines 143-147)*

*“The most important thing is that it saves time.” (Group 3, Person No: 4, Page 8, Line 268)*

Opposite to the other participants of the third group, P20 thought that using CP will lead to waste of time when used in elementary grades because of the reason that elementary level students will have difficulty in using CP.

Another role of CP that participants mentioned was visualization. 11 participants mentioned the visualization facility of the tool in the interviews and during the classroom studies. In the first group, P1 explained how much she liked mathematics by studying with the tool CP for the reason that CP provides visual representations which captured her attention and enhanced her understanding of mathematics. She was also one of the most interested students on CP during the instruction period. She used to stay in the classroom during the breaks and cope with CP, ask questions about several facilities of it, and never gave up trying during all the tasks.

In the second and third groups, all of the participants mentioned visualization as an advantage for several reasons. From the second group, P10 thinks that elementary students will get to understand more if they solve examples with CP. P19 was impressed with the visual representations of the geometry menu. Regarding to the visualization aspect of CP, P17 mentions the graphing facility of CP.

In the third group, different than the views of the second group, participants referred to the benefits of visualization such as it takes the user's interest, provides permanence, enables to compare numerous graphs, widens the point of view by

sliding and tracing facility, and provides construction of several shapes. Participants explain these advantages of visualization that CP serves in their words as:

*“Visual. Takes student’s attention more.” (Group 3, Person No: 16, Page 2, Line 49)*

*“Think of a student who knows equations, graphs, and how does he benefit from CP? For example, he would realize the difference between the graphs of  $x$  square and  $x$  square plus one. He would see better, I mean as visual... You can sketch and see both of them at the same time.” (Group 3, Person No: 4, Page 3, Lines 77-80)*

*“For example, when we say (draw)  $x$  square minus four, we slide it to left and right. When teacher draws on the board, we can only imagine. We think that when this is the case it will be that way. But as we have the option to trace the point (in CP) it is more real and more memorable. It is better... The same is valid for polygons when constructing different shapes, there is visualization.” (Group 3, Person No: 3, Page 3, Lines 87-89, 97)*

*“A wider area... I mean, as we slide coordinate axis to see its upper, down, left and right parts, you can see the rest of it. Wider.” (Group 3, Person No: 12, Page 3, Lines 90, 92-93)*

In the interviews, 5 participants mentioned the multiple representations facility of CP. They referred this facility as an advantage for mathematics learning as it provides seeing several representations such as graph of an equation and its table of variables at the same time.

*“In some equations, like  $x$  equals to  $y$  equations, we were able to see the variables of the equations in the table, and also we hold the graphs and we put it inside the coordinate axis, it was so much fun.” (Group 2, Person No: 17, Page 3, Lines 64-66)*

In the third group, 4 participants mentioned the multiple representations facility by referring to e-activity menu. As mentioned at the beginning of this chapter, e-activity enables the user to combine all of the menus in the content of the tool. Therefore, participants explained that using “more than one window at the same time is very good” as you are able to see the whole.

*“We are able to open two or three pages at the same time which is very good-one for the equation, another for the graph. In the same page you can pass to the one you want to.” (Group 3, Person No: 4, Page 7, Lines 256-257)*

*“You can see the whole, it is a very good thing according to me.” (Group 3, Person No: 14, Page 8, Line 262)*

Taking the roles they assigned to CP into account, participants argued whether CP should be used in elementary level mathematics teaching. In the first group participants expressed their ideas on the use of CP in elementary grades as “possible” (Group 1, Person No: 5, Page 6, Line 252), whereas 3 participants in the second group were strongly agree to use CP as an educational tool in mathematics courses. In the third group, all of the participants agreed to use CP as an instructional tool in mathematics courses. P3 mentioned especially the menu geometry by explaining that working with a tool that provides multiple representations “will increase elementary students’ interest” and make students “active” during the courses.

*“In my opinion, I would use CP mostly in geometry. For CP, others (menus) might be hard for students. For the figures, visualization, and taking students’ attention more in the lesson, I liked geometry menu more. It can make students more active.” (Group 3, Person No: 3, Page 13, Lines 455-458)*

Remaining participants who were not certain to use CP in their courses had concerns about being able to use CP efficiently, teaching how to use CP to students, and whether elementary students’ would use CP comfortably.

*“It is hard for a teacher to explain and teach CP.” (Group 1, Person No: 2, Page 4, Line 162)*

P20 from the third group also agreed to use CP in mathematics as an instructional tool but he had concerns about how to integrate CP in elementary level mathematics subjects. He doubt that students would depend on CP too much that they would not make any mathematical calculation by hand. P20 gave explanation to his concern as follows:

*“In algebra, for example three  $x$  plus five equals to eighty one, find  $x$ . If the kid can not solve this in mind he should not use this tool either... In elementary grade subjects the kid should use his brain, not the tool. I am agree for secondary school, in secondary grade subjects like functions...” (Group 3, Person No: 20, Page 9-10, Lines 317-318, 341-342)*

Another participant, who is from the second group, was not totally sure to use CP in elementary school mathematics courses for the reason that she had problems in operating the tool. She mentioned that she would not use the tool in all subjects; rather she would select several subjects for CP use, such as geometry.

*“It (CP) seemed complicated to me... If I am to use CP, I would use Geometry menu, for example in the subject triangles. I make use of it too much.” (Group 2, Person No: 19, Page 5, Lines 154-155)*

All the participants of the third group agreed on the idea that teachers should be capable of using CP efficiently. They believed that teacher will be the guide in the classrooms and will be responsible of helping the students in any obstacle they face while working with CP. Therefore, teachers should be experienced in using CP.

*“There can be a special class and a teacher while teaching this tool. The teacher should be a person who has mathematical knowledge and uses CP professionally.” (Group 3, Person No: 14, Page 15, Lines 557-558)*

Moreover, about teachers' management in a classroom where CP is used, 3 participants emphasized that students' works on CP should be under teacher's control. P20 showed the researcher as an example to the controlling teacher type.

*“Teacher Merve was always asking us like is there anyone who can not follow, should I help.” (Group 3, Person No: 20, Page 15, Lines 544-545)*

In addition, all the participants agreed that as they are pre-service mathematics teachers, they should have a particular course on how to use CP in university grade. P3 had an additional suggestion that CP can be useful also for science teachers in physics and chemistry courses.

Four of the interviewed participants stated that CP use would not be efficient in crowded classes. They stated reasons for this idea as at the beginning, teaching how to use CP in a crowded classroom will be hard for the teachers and during the courses, to interfere every problematic situation that students face there will be a need for extra time. P14 from the third group explained the classroom that she thinks appropriate for CP use as:

*“There can be a special class and a teacher while teaching this tool. The teacher should be a person who has mathematical knowledge and uses CP*

*professionally. For example, there should be 15 students; we were 20. 20 is also too much.” (Group 3, Person No: 14, Page 15, Lines 556-558)*

Another idea about the use of CP in mathematics courses was that courses would be different than traditional with the use of CP. In the interviews, 1 participant from the third group explained a lesson where CP is used as the main tool as follows:

*“For a student... There is no such thing that all students like mathematics. Point of view of a student who does not like mathematics might change. Firstly, the course will be out of ordinary. Secondly, as P20 said we will be able to verify ourselves.” (Group 3, Person No: 3, Page 21, Lines 780-783)*

None of the participants, except P3, directly mentioned that CP has the power to change the ordinary flow of the courses. However, in the observations and open-ended questions most of the participants mentioned that CP would change the way the courses are taught.

In addition to the idea that CP would change the flow of an ordinary mathematics course, in the third group, 3 participants mentioned that the use of CP would also lead students to discovery and research-based learning.

*“It will be beneficial for research-based education rather than memorizing. In other countries, there is research-based education.” (Group 3, Person No: 16, Page 14, Lines 500-501)*

P20 argued that in other countries students are permitted use their books in the exams, and he defended that for CP it should be the same in our country in the exams.

#### **4.2.2 Use of CP in Elementary Level**

Participants mentioned the use of CP in elementary level by emphasizing the place of the tool in lesson plans, suggested mathematical subjects for CP use and use of CP from elementary grade students’ point of view.

##### **4.2.2.1 Place of CP in a Lesson Plan**

Participants’ ideas in terms of the sub category, place of CP in a lesson plan is presented in this section (See Table 16).

Table 16. The distribution of the low, average and high group participants' views on the category, place of CP in a lesson plan

<b>a. Place of CP in a Lesson Plan</b>	<b>Low (n=4)</b>	<b>Average (n=3)</b>	<b>High (n=7)</b>	<b>Total (n=14)</b>
<b>Expressions</b>	f	f	f	f
1. CP should be integrated with paper and pencil	4	2	3	9
2. CP can be used in problem solving and exercise part of the lesson	4	2	6	12
3. There can be a application course for CP use	-	1	5	6
4. CP can be used in the warming and reminding part of a lesson	1	-	2	3
5. CP can be used in assessment and evaluation part	-	-	3	3

Participants evaluated CP in terms of its place in mathematics lessons. They mentioned the advantages of using CP in some parts and the obstacles they would face as a teacher when they use CP in other parts of a lesson.

In the first group, participants expressed that it would be hard for a teacher both to teach with CP and to manage the classroom at the same time. Therefore, they were not willing to use CP all the time in mathematics courses.

Among the participants, 12 of them suggested that CP can be used as an instructional tool in problem solving, exercise, application and activity parts of a lesson plan. All the participants in the three groups defended that CP use is meaningful and beneficial if lesson plans are formed by the integration of CP and paper-pencil tasks.

*“He (the student) will use paper and pencil. Then, use this (CP). He will learn with paper and pencil at the beginning as usual, he will understand (the subject) there, after that (he will use CP)... Student will reinforce the calculation he does on the paper better by doing it with this (CP). ” (Group 1, Person No: 7, Page 3, Lines 134-135, 137-139)*

*“In the activity part, to reinforce the lesson.” (Group 2, Person No: 10, Page 6, Line 205)*

Some participants mentioned that they would not change the usual flow of the course that as a teacher they would use the board for detailed explanation of solving problems. Then, they would choose to use CP to do further examples, near the end of the course to reinforce the subject with CP integrated tasks and activities.

*"I would solve some examples on the board. For them to see (understand) better, I would solve more examples with CP." (Group 2, Person No: 10, Page 4, Lines 127-128)*

*"The normal (traditional) teaching will remain the same. What can be done with CP? By looking at the curriculum the teacher can plan what to do. After a short training of the students, for example in the lesson teacher can explain factorization on the board, everyone uses paper and pencil, and the last 15-20 minutes near the end of the lesson he can show what he thought on this tool. Supportively..." (Group 3, Person No: 4, Page 11, Lines 395-398)*

*"Teacher can teach the subject on the board with paper and pencil as usual during the course hour. It should be same as today's teaching type, but also for application using CP to reinforce more, to make more practical is more reasonable." (Group 3, Person No: 14, Page 16, Lines 583-585)*

Particularly, a separate course - application course - in which students would do exercises with CP was suggested by 1 participant from the second group and 5 participants from the third group. Most of the participants confirmed the idea that mathematics and technology should be integrated.

*"I think, students should know how to use this (CP) very well. Especially there should be a course just for this in schools. Like an application course. Then it will be better I think." (Group 3, Person No: 16, Page 2, Lines 49-51)*

*"Subject will be explained. After that, as P16 said you go on with this (CP). I mean, combination of both of them, relation of technology and mathematics." (Group 3, Person No: 4, Page 2, Lines 60-61)*

*"This should be used in application courses... In application courses they will focus only on this (CP) and study with this (CP)." (Group 3, Person No: 3, Page 16, Lines 580-582)*

In addition to the use of the CP in exercise part of the lesson, 2 participants referred to the warming and reminding part of a lesson plan for CP use. They explained the advantage of using CP in the beginning of the course, as students would gain a basic understanding about what they will learn through the course;



students can work on quick exercises on CP in a short time by leaving the calculations to the tool and benefit from the visualization and multiple representations provided by CP.

*“In the warming part, firstly we can provide the student to see it (the subject) directly on this (CP). The child will have an idea about it (the subject). Then, his interest will grow up. First explain, solve some examples. After the examples, make them have practice on this.” (Group 1, Person No: 1, Page 6, Lines 243-245)*

*“It can be used at the first part, for example warming part by downloading different programs... Actually, it is up to the content of the subject, too. As we consider for 6<sup>th</sup>, 7<sup>th</sup> and 8<sup>th</sup> grades, according to the subject it can be planned...” (Group 3, Person No: 21, Pages 12-13, Lines 450-453)*

Three participants from the third group stated that CP can be used in assessment part of the mathematics courses. Participants also expressed that students should be allowed to use CP during the exams. Hence, they believed that this would enhance learning and using the tool more efficiently when students are permitted to use the tool in their exams, too.

*“If we enter exams with CP, we will have a chance to check if the works we make are correct or not.” (Group 3, Person No: 20, Page 14, Lines 512-513)*

#### 4.2.2.2 Suggested Subjects

Participants’ ideas in terms of the sub category, suggested subjects for CP use is presented this section (See Table 17).

Table 17. The distribution of the low, average and high group participants’ views on the category, suggested subjects

<b>Suggested Subjects</b>	<b>Low (n=4)</b>	<b>Average (n=3)</b>	<b>High (n=7)</b>	<b>Total (n=14)</b>
<b>Expressions</b>	<b>f</b>	<b>f</b>	<b>f</b>	<b>f</b>
1. CP can be used in graphing and geometry	3	3	3	9
2. CP can be used in every subject of mathematics	1	-	-	1
3. CP can be used in the subject patterns	-	2	-	2
4. CP can be used in equations	-	-	5	5

In all of the three groups, the common idea was that CP should be used mostly in subjects including algebra, coordinate axis, graphing, and geometry.

For graphing, working on CP in three-dimensional graphs, seeing changes in the graphs visually, easy and accurate comparison of the graphs by having the opportunity to draw more than two graphs on the same coordinate axis and zooming function was mentioned. Participants emphasized the graphing facility of CP as:

*“We learned to compare two graphs.” (Group 1, Person No: 7, Page 2, Line 50)*

*“Graphing was very good in terms of being visual, we are able to see what is what in the exact place, we can zoom in, we can zoom out.” (Group 1, Person No: 2, Page 2, Lines 51-52)*

Use of CP in geometry was also considered to be appropriate in terms of easy, quick and accurate construction of figures, visualization, and multiple representations of figures and numerical expressions of the dimensions. In addition, two participants expressed the appropriateness of CP use in patterns.

*“In my opinion, I would use CP mostly in geometry... For the figures, visualization, and taking students’ attention more in the lesson, I liked geometry menu much more. It can make students become more active.” (Group 3, Person No: 3, Page 13, Lines 455-458)*

*“It showed the patterns more accurate... We took the squares of them (numbers). Then after a point we saw how it is repeating.” (Group 2, Person No: 10, Page 2, Line 55, 57)*

Using CP in every mathematical subject was an idea of 1 participant from the first group that she believed every mathematical operation can be done with CP.

*“It can be used in every subject. For example, if we think of a young child, he will make adding and subtraction in elementary school, he can use it (CP) there. In high school level it (the use of CP) is different. But in every subject it can facilitate everyone’s work.” (Group 1, Person No: 1, Page 5, Line 224-226)*

In the third group, 5 participants stated that CP could be used in learning and teaching of equations in elementary level. P20 was not included in the percentage of

the participants who suggested CP use in the subject equations because he stated that; although CP is a practical way of solving equations, this will be ready information for elementary grade students. P20 thinks that students in elementary level should make calculations by using their brains. He expressed the reason of his idea by giving an example as in the following excerpt.

*“In algebra, for example three x plus five equals to eighty one, find x. If the kid can not solve this in mind he should not use this tool either. In those simple subjects or in that hard candle question I was answering mentally; writing it in here is waste of time. In these subjects, I would not use paper and pencil, too... In elementary grade subjects, the kid should use his brain, not the tool. I am agree for secondary school, in secondary grade subjects like functions...” (Group 3, Person No: 20, Page 9-10, Lines 317-320, 341-342)*

Other participants suggested CP use in equations for several reasons. P4 expressed that practicality of CP provides time saving but in the early levels of elementary school, use of CP would not be appropriate. He suggested the use of CP in learning equations by starting in grade 6. He also stated that learning equations with a GC would be “appealing” for a student in elementary level. As an answer to P20 who thought that use of CP is not appropriate in elementary level as students would depend on CP; some participants explained that CP will be beneficial if used in the learning and teaching of the subject equations.

*“How much this tool is appealing for you in learning integral, that much appealing for a kid to solve equations.” (Group 3, Person No: 4, Page 9, Line 329)*

*“ (A student) He might be able to solve the problem, able to calculate it mentally. But from the view of increasing his attention to the lesson, writing something on it (CP), plus sketching its graph...” (Group 3, Person No: 3, Page 10, Lines 344-345)*

#### **4.2.2.3 Elementary Grade Students’ Use of CP**

Participants’ ideas in terms of the sub category, elementary grade students’ use of CP from pre-service teachers’ point of view is presented in this section (See Table 18).

Table 18. The distribution of the low, average and high group participants' views on the category, elementary grade students' use of CP

<b>Elementary Grade Students' Use of CP</b>	<b>Low (n=4)</b>	<b>Average (n=3)</b>	<b>High (n=7)</b>	<b>Total (n=14)</b>
<b>Expressions</b>	<b>f</b>	<b>f</b>	<b>f</b>	<b>f</b>
1. I doubt if elementary grade students would understand the aim of CP	1	-	-	1
2. CP can condition the students for ready-made answers	3	1	2	6
3. Students should be capable of using CP	1	2	7	10
4. CP widens students' point of view	-	1	3	4
5. CP can be very beneficial for talented students	-	-	1	1
6. CP will increase students' attention	1	2	6	9
7. CP provides verification	-	1	3	4
8. Students should take CP home	-	-	3	3
9. Students should not take CP home	-	-	2	2
10. CP will make students like mathematics	3	1	1	5
11. CP provides students learn and do calculations faster	3	2	-	5

Participants made comments on the use of CP in mathematics by considering themselves as elementary grade students and they made comments from a pedagogic point of view considering their experiences with CP in the 5-week instruction period.

In the first group, 2 participants expressed that elementary grade students might have problems in realizing the actual aim of the tool.

*“When we consider ourselves, it (CP) is absolutely appropriate but, as they are children being unaware of anything, would they get to understand this tool? Or think this as a game? That is what I am concerned about.” (Group 1, Person No: 1, Page 3, Line 125-127)*

Some participants doubted that as CP gives directly the answer, how a student would get to reach the answer by himself. P4 and P20 mentioned that CP

would cause students get used to ready-made information, as it does not show the steps of calculations, instead gives the final answer. Participants expressed this as:

*“This tool directly solves the question, skips the steps, gives the result directly. For example, when we solve a question we do step by step, I mean we do the summing, subtracting. This (CP) makes us solve the question directly.” (Group 1, Person No: 5, Page 3, Lines 130-132)*

*“We will make the students sketch parabolas. We write the graph (equation of the graph) here, it directly sketches. When we draw (with paper and pencil), we find the vertex and so on. How will the student get to find it? How will we teach this in the GC?” (Group 2, Person No: 10, Page 4, Line 111-113)*

In the second group, 1 participant expressed that she was feeling uncomfortable with CP and so students would. She explained her concern as follows:

*“If I am to talk about my experiences, some menus seemed complicated to me. I was having difficulty especially in e-activity, I was confused very much... I am even having trouble, they (elementary students) will also have trouble in any case.” (Group 2, Person No: 19, Page 5, Lines 149-150, 157)*

Participants expressed that it is a need for elementary school students to be capable of using CP, to understand the actual aim of the tool, in order not to depend only on CP, and to maximize the efficiency of the use.

*“After having learned, they can benefit more from this. I mean we can not benefit totally because we only use as far as we know.” (Group 1, Person No: 1, Page 5, Lines 209-210)*

As an advantage of CP, some participants stated that the tool would widen students' point of view. Some of them defined the blackboard as limited. In contrary, they defined CP as unlimited that it provides zooming and sliding functions in geometrical figures and graphing.

*“I would solve some examples on the board. For them to see (understand) better, I would solve more examples with CP.” (Group 2, Person No: 10, Page 4, Lines 127-128)*

*“For example, when we say (draw)  $x$  square minus four, we slide it to left and right. When teacher draws on the board, we can only imagine. We think that when this is the case it will be that way. But as we have the option to trace the*

*point (in CP) it is more real and more memorable. It is better...* (Group 3, Person No: 3, Page 3, Lines 87-89)

*"A wider area... I mean, as we slide coordinate axis to see its upper, down, left and right parts, you can see the rest of it. Wider."* (Group 3, Person No: 12, Page 3, Lines 90, 92-93)

Most of the participants emphasized that as it is a technological tool, CP can increase students' attention. Moreover, participants exemplified some situations for CP use such as; while doing homework, when there is a need for seeing multiple representations together, and when a teacher would like to change the flow of the lesson with an instructional tool to conduct practical exercises.

*"It (CP) will make the students like mathematics."* (Group 3, Person No: 14, Page 21, Line 763)

*"For example, a student does not want to do homework, revise the lesson at home. But if there is CP, he would try to do it more enjoying. He would not strive with homework but he would try with CP."* (Group 1, Person No: 2, Page 3, Lines 93-95)

*"I thought from students' point of view by empathizing. It (CP) was very beneficial for me. In what ways? If I were a student... It takes my attention, increased my interest on the subject. For example, you write here, practical, you write the equation it solves true... Increased my interest on the subject. As I said, if I know the subject I will be more practical."* (Group 3, Person No: 4, Page 8, Lines 294-297)

*"Today's children learn how to use a computer until first grade. They are interested in technological tools more. Instead of carrying lots of things such as notebook, paper, pencil, bag; carrying this (CP) makes more sense to me."* (Group 3, Person No: 21, Page 23, Lines 832-834)

According to some of the participants, there are other facilities of CP for elementary school level students. Participants frequently expressed that CP would provide students to verify their calculations, contains functions for quick and accurate sketching and doing complex operations in mathematics. Some participants assigned verification role to CP and they stated that CP would take the place of a teacher, in particular, with its verification role.

*"For example, when I ask a problem related with interior angles or exterior angles... I will ask them to solve by using CP... They will compare their*

*answers. CP will show them (students) where they made mistakes. They might not need a teacher... They will actually but they might understand without asking a question.” (Group 2, Person No: 17, Page 5, Lines 141-145)*

*“Teacher gives homework. You make the calculations, but you are not sure about the result. By writing it here (CP), you can verify.” (Group 3, Person No: 3, Page 11, Lines 401-402)*

*“If we enter exams with CP, we will have a chance to check whether the works we make are correct or not.” (Group 3, Person No: 20, Page 14, Lines 512-513)*

In the first and third groups, some participants expressed that CP would provide students do calculations faster than doing by hand and give accurate solutions; therefore, they would learn faster.

*“CP will show them (students) where they made mistakes. They might not need a teacher... They will actually but they might understand without asking a question. In that point, time will be saved. Because, rather than intervening to 40 students, intervening only one student who does not understand is better for me. I will solve more examples.” (Group 2, Person No: 17, Page 5, Lines 143-147)*

Apart from elementary school level students’ use of CP during mathematics courses, participants argued whether they should take CP home. Participants who were against taking CP home, reasoned their view as students might spend too much time with CP at home that they would quit studying for other courses.

*“I do not agree with taking CP home. Because, there is not only mathematics lesson but also a lot of lessons in elementary school. They (students) will just focus on this... Most of our lessons are related with mathematics. But they have many different lessons; their department is not mathematics. They will give all their attention to this (CP).” (Group 3, Person No: 14, Page 13, Lines 470-471, 476-479)*

*“This (CP) should be used in application courses. For 6<sup>th</sup>, 7<sup>th</sup> and 8<sup>th</sup> grades, it is unnecessary to take the tool home and use it at home.” (Group 3, Person No: 3, Page 16, Lines 580-581)*

By supporting the view that students should also use CP at home, P4 stated that teacher could limit students’ use of CP. In addition, P20 mentioned that students would not strive with the tool too much after they complete their homework.

*“You can limit the use.” (Group 3, Person No: 4, Page 13, Line 484)*

*“He (a student) will do his homework, and he will be dying to finish the homework and go out.” (Group 3, Person No: 20, Page 13, Line 485)*

#### 4.2.3 Suggested Grades for CP Use

Participants’ ideas in terms of the sub category, suggested grades for CP use is presented in this section (See Table 19).

Table 19. The distribution of the low, average and high group participants’ views on the category, suggested grades for CP use

<b>Suggested Grades for CP Use</b>	<b>Low (n=4)</b>	<b>Average (n=3)</b>	<b>High (n=7)</b>	<b>Total (n=14)</b>
<b>Expressions</b>	<b>f</b>	<b>f</b>	<b>f</b>	<b>f</b>
1. Students should start to use CP in 4 <sup>th</sup> and 5 <sup>th</sup> grades	3	-	1	4
2. Students should start to use CP after the first five grades	-	2	7	9
3. Students should start to use CP in secondary grade	1	1	4	6
4. CP can be used in university level	2	1	-	3

Participants expressed views on the education grades for CP use ranging between the first year of elementary grade until the end of university education. They also referred to the use of CP in professional life as mathematics teachers.

Participants defined elementary school education in two parts; the first 5 years and the last 3 years of elementary school. They stated confirmation or objection to the use of CP in elementary level by referring to elementary years in two parts.

The underlying idea was that participants recommended the use of CP starting from the 6<sup>th</sup> grade. 9 participants defended that use of CP is not beneficial before 6<sup>th</sup> grade whereas 4 participants defended that the early the student get close with the tool, the more he benefits from it in the following years.

In the first group, 3 participants offered that students should meet CP in elementary school, in grades 4 and 5.



*“(Use of CP) Can start in the 4<sup>th</sup> grade and (use) more in high school... As they are more curious in small ages, they would enjoy to learn this more.” (Group 1, Person No: 1, Page 5, Lines 190, 207-208)*

By confirming that a student would start to use CP early in education, participants added that use of CP would be endless in educational life in the following years of education.

*“And use it until the end of the educational life.” (Group 1, Person No: 7, Page 5, Line 196)*

In the second group, participants confirmed that use of CP is appropriate in elementary grades higher than the 5<sup>th</sup> grade. One idea was that 7<sup>th</sup> grade is appropriate for CP use for the reason that there are mathematical subjects to be carried out with CP such as equations. Another idea was that students should meet CP in their early ages, whereas they should use it more frequently in university level. The reflections were as follows:

*“Grade 7 because there is graphing, there is equations.” (Group 2, Person No: 10, Page 7, Line 220)*

*“Let’s say that every student saw CP in elementary grades but in several periods, grades 7, 8 or 6, 7, 8. They only used it only when they are bored or they met the tool in some ways. All the students know (how to use) the tool, but their training will be in the university.” (Group 2, Person No: 17, Page 7, Line 234-237)*

In the third group, all of the participants agreed that students should start to use CP in 6<sup>th</sup> grade as an educational tool in mathematics courses. They reasoned this idea with several supports. Firstly, before the 6<sup>th</sup> grade students do not learn discrete concepts in mathematics, they rather use concrete objects or figures related with daily life in mathematics courses. Secondly, in terms of the mathematical subjects in the curriculum for 6<sup>th</sup>, 7<sup>th</sup>, and 8<sup>th</sup> grades, these grades are appropriate for CP use.

*“When we look at its (CP’s) content, there is no subject to be used before the 6<sup>th</sup> grade. As P20 said, they make calculations with apples instead of  $x$  and  $y$ .” (Group 3, Person No: 14, Page 19, Lines 682-683)*

*“Before (6<sup>th</sup> grade), as a student will not be able to think discrete, he needs a shape. He needs to see apple instead of x.” (Group 3, Person No: 21, Page 19, Lines 689-690)*

*“In grades 6, 7 and 8, they can just get familiarize with this tool or in application courses they can use geometry menu or graphs. When students start to secondary school they will have full knowledge of all subjects.” (Group 3, Person No: 3, Page 19, Lines 694-696)*

P3 from the third group suggested a period of increasing frequency in CP use. She defended that students should meet with CP in 6<sup>th</sup> grade and in every following year students' use of CP should increase. After students have a background about mathematical subjects, they should be provided with a preparation period of using CP with all its functions in the beginning of secondary school. P3 also added that teachers should be responsible of the use of CP and decide where CP use would be beneficial for learning mathematics.

*“When all the subjects are completed, for example when students are stepping to high school, it (CP) might be taught as a preparation period... When students have some basic information... I think at 6<sup>th</sup> grade. In middle grade (6<sup>th</sup>, 7<sup>th</sup> and 8<sup>th</sup> grades), teacher should show, introduce this to students, and they should start using at secondary grades. They will get used to it (CP) slowly. ” (Group 3, Person No: 3, Page 2-18, Lines 63-66, 79-81)*

P4 from the third group suggested CP use be optional for students in elementary grades, for instance students who are interested in mathematics more would deal with CP more than the others.

*“What makes sense to me is students who have interest on mathematics. I mean, ones who are preparing for olympiads. These olympiads start at 6<sup>th</sup> and 7<sup>th</sup> grades. To understand mathematics better, to develop mathematical thinking.” (Group 3, Person No: 4, Page 3, Lines 74-76)*

In spite of the appropriate use of CP in elementary levels, the other suggestion was that secondary school is appropriate for CP use. 1 participant in the first group and another from the second group suggested CP use in secondary grades because the subjects in secondary school mathematics can be operated via CP. Participants explain their reasons as in the following excerpts:

*“For me, a child should learn several things very well then start (to learn) practical things... Teaching with CP in high school or at the end of elementary grades is better.” (Group 1, Person No: 2, Page 5, Line 201-203)*

*“If I were to decide I would use it in high school. Because it (CP) can be used more in subjects such as graphs, integral.” (Group 2, Person No: 19, Page 7, Lines 242-243)*

In addition to the suggestions of CP use in elementary grades, P3, P4, P20, P21 highly recommended CP use also in secondary grades. In the third group, 7 participants referred to the use of CP in secondary level.

In the interviews, although only 3 participants stated that they were willing to use CP in university grade and after university in their professional lives as elementary mathematics teachers; during the instruction process majority of the participants were searching websites for CP and other GCs to get one for themselves.

*“We also can use, after getting started to work when we are a teacher, too.” (Group 3, Person No: 21, Page 19, Line 701)*

#### 4.2.4 Comparison of CP with Paper and Pencil

Participants’ ideas in terms of the sub category, comparison of CP with paper and pencil is presented in this section (See Table 20).

Table 20. The distribution of the low, average and high group participants’ views on the category, comparison of CP with paper and pencil

<b>Comparison of CP with paper and pencil</b>	<b>Low (n=4)</b>	<b>Average (n=3)</b>	<b>High (n=7)</b>	<b>Total (n=14)</b>
<b>Expressions</b>	<b>f</b>	<b>f</b>	<b>f</b>	<b>f</b>
1. Make more regular and correct drawings	3	3	6	12
2. Using CP saves time	2	1	2	5
3. CP provides comparison of a number of graphs.	1	-	2	3
4. Widens your view.	-	-	4	4
5. CP helps you to remember the things you forget.	-	-	2	2

Participants emphasized the facilities of CP by comparing the tool with paper and pencil. They mentioned these facilities as getting reliable drawings of graphs and geometric figures, checking answers and thus saving time while doing these mathematical operations. Participants generally used the word “practical” for the facilities of CP. They also pointed that the time was saved when tasks were conducted with CP when compared to paper and pencil.

All of the participants mentioned the superiority of CP than paper and pencil as it provides immediate change in graphs, comparison of many graphs in single coordinate axis and provides functions for other drawings such as constructing images in geometry menu.

*“Think of a student who knows equations, graphs, and how does he benefit from CP? For example, he would realize the difference between the graphs of  $x$  square and  $x$  square plus one. He would see better, I mean as visual. Maybe it is not hard to sketch two graphs but sketching with CP is easier. You can sketch and see both of them at the same time.” (Group 3, Person No: 4, Page 3, Lines 77-80)*

Twelve of the interviewees mentioned the correct and regular drawings that CP serves to its users, which can be energy and time consuming when done by hand with paper-pencil. Moreover, participants emphasized that drawings made by hand with paper-pencil are not totally reliable at all. For instance, there was a task in the last course about constructing a geometrical figure (See Appendix A). During the task, participants were expected to change the dimensions of a regular rectangle in order to make the opposite sides equal. P2 gave an example from her experience during that task.

*“We drew (constructed) a rectangle. There, we made one side 2 (units). If we were to draw it on the notebook, we have to draw by using a ruler. That would have been harder.” (Group 1, Person No: 1, Page 2, Lines 182-183)*

*“The most important thing is that it saves time.” (Group 3, Person No: 4, Page 8, Line 268)*

In addition to the first group, all the participants of the third group defined the regular drawing capability of CP as an advantage both for their use of CP and

elementary students' use of CP. Participants gave examples such as geometrical shapes which they consider as difficult to draw regularly and in correct dimensions by using a ruler with paper and pencil.

*"We drew pentagon and etc. That would also be hard (to draw) with paper-pencil." (Group 1, Person No: 5, Page 4, Line 181)*

*"We can draw every thing very regular, like figures, graphs, geometrical shapes." (Group 1, Person No: 2, Page 4, Line 168)*

*"For example it draws geometrical shapes very regular. We can also draw by using ruler but it (CP) arranges itself." (Group 2, Person No: 17, Page 3, Lines 90-91)*

In addition to regular construction of geometrical figures, the easy sketching of graphs and the regular coordinate axis that CP provides were also mentioned by most of the participants. When they sketched several graphs on the same coordinate axis, they expressed that they were impressed with the regular drawing appeared on the axis in a very short time. Moreover, some of the participants mentioned that complicated graphs that have fractional values were also sketched regularly and comparison of the graphs was easy with several functions in the tool such as zooming, dragging and padding.

*"Even if it is fractional, or for the coordinates, even if the angles are fractional, it (CP) can measure and show it." (Group 2, Person No: 10, Page 3, Lines 94-95)*

*"Shows more than two graphs on the same graphing (window), you can see their differences. When we draw them on the notebook we mix them like one goes from up, one goes from there. You need to use colorful pencils but here, it (CP) shows the differences of them all." (Group 3, Person No: 20, Page 21, Lines 775-777)*

*"We can not do some other things with paper-pencil such as some graphs. For example, we forget some graphs or we change their maximum and minimum points. More practical." (Group 3, Person No: 16, Page 2, Line 45-47)*

Participants gave several reasons for CP use instead of paper and pencil. Some of them expressed that they would give up doing calculations, constructing figures, or drawing various graphs. Therefore, they defined CP as a beneficial tool

that leads discovering and learning mathematics as long as it provides accurate data. Similarly, P20 explained a situation considering his habits such as his writing and drawing is not very regular. He stated that CP writes, draws and sketches more regular, and measurements in CP are more reliable than his calculations. Hence, he preferred CP instead of paper and pencil. He explained the effect of this situation as follows:

*"I am too lazy to sketch graphs in coordinate system. GC was better for me."*  
(Group 2, Person No: 19, Page 3, Lines 98-99)

*"Effects my perception. You perceive easier; because, I mean, you take note during the courses, you go home, than you look and say 'did I draw this wrong, did I make a mistake when drawing'. But there is no such thing in this (CP)."* (Group 3, Person No: 20, Page 8, Lines 271-273)

P14 confirmed P20 by adding that there occur mistakes while copying mathematical from board to notebook so the reliability of the information on paper and pencil decreases.

*"Sometimes we can not write exactly the same things on the notebook that teacher draws, we sometimes miss something or lack of attention and because of these we can not copy exactly the same things. The rate of doing mistake is very high."* (Group 3, Person No: 20, Page 8, Lines 275-277)

*"When we change the number (value) the figure changes itself, I mean if we had done it on the notebook, erase it, then draw it over again from the beginning. Also there is a risk of erasing other things while erasing that, too. But in this (CP) there is not such thing."* (Group 1, Person No: 5, Page 4, Line 171-173)

Whereas, P14 added that taking notes on CP during course hour cause waste of time as they could not use the keyboard comfortably which sometimes resulted in waste of time. P14 suggested writing the questions on the notebook and making the calculations and drawings, anything needed for the solution process with CP. As a solution, P3 and P4 explained that more experience with the tool would make students more practical and quick enough to write down the questions on CP.

P17 from the second group gave another similar example about a common student habit. She expressed that students who do not use notebooks properly or who

has very proper notebooks face some difficulties such as sometimes they miss some information and do not write down the notes during the courses. She explained that CP is an option for both kinds of students that it provides free noting and downloading. While the student only solves given problems during mathematics courses but do not note down the subject properly - because he does not like writing everything down or because he does not have his mathematics notebook that day - he can save those solutions and when he looks them up later, these solutions would give him an idea about the course although he does not have any notes on his notebook.

*“As an example, we can lose our pencils, notebooks or be obsessive like never writing (mathematical notes) on our Turkish course notebook. But in this (CP) there is no such thing; you can save in here (CP), you can send it (the notes that are saved) to your computer when you go home or turn it (CP) on and copy notes from there to your notebook by yourself. From this aspect, it is an advantage and also more enjoyable, interesting.” (Group 2, Person No: 17, Page 3, Lines 84-87)*

When participants were asked what they would refer as an advantage of the tool when it is compared to paper-pencil, P17 stated that the tool gives “true” information. The situation that CP provides comparison by producing “true” results was also stated in the example that P17 stated. Researcher, in specific, asked the difference between sketching a graph with paper-pencil and with CP.

*“True (result). We might make mistakes; we might calculate the variables wrong (with paper-pencil). For example, a graph might be wrong, I mean it (paper-pencil) might lead us to sketch the graph wrong. But here (in CP) there is almost millimetric calculation; it immediately solves anything. Or you can sketch by yourself (with paper-pencil) and see your mistake there in the tool. By comparing you see where the difference is, where you made a mistake.” (Group 2, Person No: 17, Page 4, Lines 102, 104, 106-108)*

P1 from the first group mentioned the facility of CP which resembles to paper and pencil. In CP, there is a function to take notes anywhere you want which serves a platform to the user that can be used like a notebook. P1 emphasized the place at the bottom part of the graphs where you can note anything about the graph.

*“We can write any information we want on the top of the graphs.” (Group 1, Person No: 1, Page 4, Line 170)*

In the third group, the idea that CP widens the users' view was expressed. 4 participants in the third group mentioned that CP gives a wider area than paper-pencil; the area that provides the participants to see rather than imagine. Moreover, participants mentioned that they see more in CP, all parts of the graphs by zooming in and out, by sliding the figures. They also added that, this wider view makes the subject more permanent and enhances learning. In order to reflect how participants recall their experiences about CP's facility that it showed an infinite area in drawings, excerpts from the interview is given below:

*"For example, when we say (draw)  $x$  square minus four, we slide it to left and right. When teacher draws on the board, we can only imagine. We think that when this is the case it will be that way. But as we have the option to trace the point (in CP) it is more real and more memorable. It is better... The same is valid for polygons when constructing different shapes, there is visualization."* (Group 3, Person No: 3, Page 3, Lines 87-89, 97)

*"A wider area... I mean, as we slide coordinate axis to see its upper, down, left and right parts, you can see the rest of it. Wider."* (Group 3, Person No: 12, Page 3, Lines 90, 92-93)

Two participants mentioned that CP helps the user to remember the things he forgets which is a facility similar to a notebook. They also added that CP could give you any information that does not take place in the notebook. To explain her view on the benefits of the recall that CP provides to the students, P21 gave an example of a lazy student:

*"There are a lot of students who does not take notes and does not have notebook in high school. He (a student) does not sketch the graph. Then, the exam day comes; he thinks 'what did we do'. It will provide benefit for him as here (CP) occurs the graph immediately when he writes an equation."* (Group 3, Person No: 21, Page 21, Lines 770-772)

### **4.3 CP and Motivation**

Participants' ideas in terms of the category, CP and motivation is presented in this section (See Table 21).



Table 21. The distribution of the sub, average and high group participants' views on the category, CP and motivation

<b>CP and Motivation</b>	<b>Low (n=4)</b>	<b>Average (n=3)</b>	<b>High (n=7)</b>	<b>Total (n=14)</b>
<b>Expressions</b>	<b>f</b>	<b>f</b>	<b>f</b>	<b>f</b>
1. Visual	1	-	2	3
2. Enjoyable	2	1	3	6
3. Practical	-	-	2	2
4. Takes attention	1	3	5	9
5. Helps in revision	1	-	-	1
6. Better when compared with computers	2	-	-	2
7. Missing a step causes disconnection	3	1	4	8
8. Teacher interference is necessary	1	-	4	5
9. Builds up passion and wonder	4	3	3	10
10. Correct and quick sketching	1	3	1	5
11. Effective in overcoming the prejudice against mathematics	1	1	1	3
12. Encourages competition between peers	-	1	1	2
13. It can be boring when used too often	1	2	1	4
14. Slows you down	-	-	1	1
15. Helps in recall	-	-	2	2
16. Makes students active and encourages active attendance to lesson	-	-	5	5

All of the participants with no exception emphasized that CP captured their interest more than any other tool or education method that they had had experienced before. Participants defined CP as an enjoyable tool for the reason that it presents visualization and provides ease in calculation.

Most of the participants expressed that the visual representations and practicality in calculation took their attention and they wanted to work with CP with desire. Specifically, P1 expressed that she was not a successful student in mathematics because she did not understand several subjects. Therefore she was not interested in mathematics courses. She explained that there occurred a positive

change in her attitude towards mathematics after she met CP. She gave several reasons for this change. Firstly, she mentioned that she gained her self-confidence in terms of mathematical success when she did not make mistakes in calculations as the tool did the operations accurately. Secondly, she expressed that lack of mathematical knowledge did not limit her as CP serves the needed functions to operate and construct the steps in the tasks during the classroom studies. In brief, she emphasized that these facilities of CP led her to feel that she was learning, therefore started doing mathematics willingly.

*“I normally don’t like mathematics I even hate it. I don’t even want to attend the courses. I don’t understand much, either. But this tool itself make the calculations, you see everything. As it is enjoyable, I liked it. It is like I feel more self-confident... I found (CP) sympathetic, because as mathematics is generally writing and drawing with pencil, trying and so on... But in here (CP) you see and have fun.” (Group 1, Person No: 1, Page 2, Lines 63-66, 70-71)*

In addition to the visualization facility of the tool, CP was considered as enjoyable and practical. In addition, some participants mentioned that the wonder to learn more functions of the tool and they had the opportunity to benefit from CP as they experience with the tool more, made CP interesting for them.

*“As a mathematician especially in graphs, functions and etc, it could become a part of our lives. In my opinion, if we work on it some more, improve ourselves more, we can benefit from it. Five weeks was short, but even in this period, if I am to talk about myself, I really both had fun and learned a lot of things.” (Group 3, Person No: 3, Page 2, Lines 40-44)*

*“It (CP) effected my motivation in a positive way. I generally can not motivate and focus on anything permanently. But, as this (CP) is interesting and we explore things, all my interest was on this.” (Group 1, Person No: 1, Page 7, Lines 306-308)*

Two participants from the first group compared the period, before and after the instruction process with CP in the CSE course. They mentioned as they became more willing to participate the lesson after they met CP. In addition, they explained that it was obvious from their participation rate to the course that they were not interested in CSE course before CP. In brief, participants clearly stated that they

were more interested in the course when they only focused on CP than a course dealing with computers and internet.

*“Our courses before using CP... Computers are enjoyable but boring, you do not want to come to the lesson, you think like no matter if do not attend the lesson. But after we started to use CP... We were willing to join the courses.” (Group 1, Person No: 2, Page 7, Lines 311-313, 316)*

Majority of the participants in the three groups stated that CP builds up one's interest and curiosity in any level and task. In the second group, it was expressed that CP leads one to be curious with its content and functions such as zooming, multiple representations of figures and dimensions, dragging graphs and equation to interchange them and so on. This was also observed during the instruction process that, although there were times participants had difficulty and could not carry on the steps to complete the tasks, none of them gave up trying until they succeed in the tasks.

*“Although we sometimes missed some steps in some menus, we tried to succeed, complete and catch you. We could not leave the tool. We always went on.” (Group 2, Person No: 17, Page 10, Lines 328-329)*

*“It effected (motivation) in terms of curiosity. It (CP) held my motivation higher. How will it be? How will we do this? We zoom in and out on graphs and etc.” (Group 2, Person No: 10, Page 10, Lines 340-341)*

*“We learned as took our attention. In every lesson, we were always saying ‘ah is it, it can also do this, let me also do that...’ ” (Group 3, Person No: 21, Page 22, Line 800)*

Specifically, most of the participants mentioned that among its functions, quick and correct sketching of CP effected their motivation in a positive way.

*“I normally don't like mathematics I even hate it. I don't even want to attend the courses. I don't understand much, either. But this tool itself make the calculations, you see everything. As it is enjoyable, I liked it. It is like I feel more self-confident... I found (CP) sympathetic, because as mathematics is generally writing and drawing with pencil, trying and so on... But in here (CP) you see and have fun.” (Group 1, Person No: 1, Page 2, Line 63-66, 70-71)*

In the second group, after P10 and P17 mentioned that CP takes attention, researcher asked them what took their attention in specific. P17 showed the geometrical construction in CP as the reason of her interest on using CP.

*“For example it draws geometrical shapes very regular. We can also draw by using ruler but it (CP) arranges itself.” (Group 2, Person No: 17, Page 3, Lines 90-91)*

Prejudice against mathematics would be out of discussion with the appearance of CP, as three participants expressed. Considering the facilities mentioned above that CP provides to users, participants expressed that CP has the power to make one like to deal with mathematics. Similarly, from elementary grade students’ point of view, participants explained that providing visualization makes mathematics more concrete, direct feedback builds up passion to go on studying, students would save their work on CP memory, can create their own exercises while they try to explore function of several menus, and study freely on CP without the fear of making mistakes.

*“For a student... There is no such thing that all students like mathematics. Point of view of a student who does not like mathematics might change. Firstly, the course will be out of ordinary. Secondly, as P20 said we will be able to verify ourselves. Yes, maybe we can do calculations from our memory but when we see that here (CP) it is a concrete example of it.” (Group 3, Person No: 3, Page 21, Lines 780-784)*

With the increasing interest and passion, two participants from the second and the third groups mentioned that CP would lead students to competition which they believed would increase learning.

*“They (students) will come from elementary school where they have not used CP in grades 1, 2, 3, 4 and 5 and we will teach them how to use CP. As it will be very interesting, if they do not want to listen – as sometimes they come to mathematics courses with some prejudices – maybe they will be able to overcome the prejudices. They will learn more enjoyable with the tool, they might compete with each other in the class as well.” (Group 2, Person No: 17, Page 4, Lines 133-136)*

Different than the first and second groups, in the third group 5 participants expressed that CP would make students active and encourage active participation of students during courses.

*“(A student) He might be able to solve the problem, able to calculate it mentally. But from the view of increasing his attention to the lesson, writing something on it (CP), plus sketching its graph...” (Group 3, Person No: 3, Page 10, Lines 344-345)*

*“In my opinion, I would use CP mostly in geometry... For the figures, visualization, and taking students’ attention more in the lesson, I liked geometry menu more. It can make students more active.” (Group 3, Person No: 3, Page 13, Lines 455-458)*

*“It (CP) teaches you to learn the subject during the lesson. If one of my friends or the other can do it and if I fall behind in the class, I can do it as well when you wait for me for a while. Everyone is at the same level, for example, everyone completes the first step and passes to the second altogether.” (Group 3, Person No: 3, Page 22, Lines 812-814)*

P12 adds something to P3’s idea about active involvement of students as:

*“In addition, as everyone needs to follow at that time they all focus on one point. You can not quit, because everyone has to pass to the second step.” (Group 3, Person No: 12, Page 22, Lines 817-818)*

Two participants from the third group stated that CP is a helpful and advantageous tool in recall. CP provides feedback, information, mathematical knowledge and solution ways to the students. P21 gave an example of a student who did not listen to the lesson during the course or who could not attend a mathematical course. She stated that the student has the opportunity to learn something about the subject by using CP.

Apart from its positive effects on students’ motivation; participants had some concerns that CP would form unexpected behaviors in students in terms of their interest towards learning mathematics with CP. There was a doubt among the participants about CP becoming a usual and boring habit in time when it is used very frequently. 4 out of 14 participants mentioned that CP, when used too often might cause decrease in motivation. Therefore, participants suggested that the teacher would decide specific parts of the lesson according to the subject, where he believed

that use of CP would increase understanding and learning of mathematical subjects. For instance, as P17 mentioned, during the courses CP use should be limited by the teacher, such as using the tool only in reinforcement part of the lesson.

*“I do not know if there will be a decrease in my motivation when I get used to this (CP) in the future.” (Group 1, Person No: 1, Page 7, Lines 308-310)*

*“I would use this (CP) in reinforcement, because it is not something to be used permanently. There will certainly be somebody who can not follow so I would use it sometimes only when they get bored from the lesson.” (Group 2, Person No: 17, Page 6, Lines 208-210)*

*“Using the tool for an hour might effect motivation in a negative way. It should be used just in the half of the lesson. In the fifty percent part teacher can teach, forty percent with CP and ten percent can be left for the part which we say fun part, that enables student to concentrate more on the lesson.” (Group 3, Person No: 21, Page 22, Lines 827-830)*

From the third group, P20 mentioned another disadvantage of CP that it might slow down the user if he is not capable of using it effectively. By saying effectively, P20 mentioned knowing all the menus and functions of the tool. To overcome the limitations of the tool and possible disadvantages it would cause, from the first and the third groups, 5 participants mentioned that teacher control is very important in CP use. Otherwise students would have difficulties in following the course which would cause disconnection and lack of motivation. For this reason, teacher should train students in terms of efficient use of CP and plan when and where the tool will be used.

*“Sometimes we were solving the problems altogether. When you miss a step there occurred disconnection sometimes.” (Group 1, Person No: 5, Page 7, Lines 322-323)*

*“Yes, when there is something that we do not understand, we stop. When we miss a step, it is like a chain, you miss and the rest of it does not come... There should interfere. You interfered in those parts very well.” (Group 1, Person No: 1, Page 7, Lines 325-326, 328)*

*“By looking at the level and situation of the students, teacher should plan this by himself.” (Group 3, Person No: 12, Page 22, Line 831)*

#### **4.4 Views of Pre-Service Teachers Having Different Attitude Levels**

In the present study, 21 pre-service elementary mathematics teachers were observed in the five-week process while using the GC – CP – in learning elementary school algebra and their views were investigated. All of the participants worked together during the five-week instruction process. On the other hand, for the interviews, participants were not interviewed as one group or as individuals. Instead they were grouped in three according to the results of the analysis of the three attitude scales. The scales were aimed to measure the pre-service teachers' attitudes on mathematics, technology, and learning mathematics with technology. The first, second and third group of the focus group interviews were named as low, average and high groups corresponding to the attitude levels of the participants (See section 3.2.1.4 for detailed information about forming the interview groups).

Pre-service elementary mathematics teachers with different attitude levels viewed CP in different forms and their views were reported as a personal tool in the beginning of this chapter. In all of the three groups, participants commonly mentioned that they enjoyed using CP and they would be better users if they had more experience with the tool. In the first group, participants perceived CP as a tool which is easy to understand, use, and manage. However, they did not mention any specific function as important for a mathematician as the participants in the third group. On the other hand, in the third group, that has the highest attitude level, participants mentioned their interest and other people's interest around them on CP. About the physical features and technological equipment of the tool, there were not as many comments in the second group as in the other groups. The common ideas in the first and third groups were that they suggested the tool connect to internet, the screen of the tool be lightened and colorful, and a video camera would be integrated to the tool. In addition to the comments in all of the three groups, the third group that had high attitude level mentioned that CP and computer connection was an advantage for teachers and students in classroom environment. The sub and high

groups mentioned a negative comment that touchpad sometimes caused problems in managing the tool.

Participants viewed CP in terms of its functions, menus, and content. The common view in the three groups was that they enjoyed and benefited from geometry and e-activity menus. CP provided calculation, equation solving, and graphing functions which participants mentioned as beneficial in all of the three groups. Participants in the third group presented different ideas than the other two groups in terms of the suggestions they made about the content of the tool such as the language of the menu be native, in Turkish. They were eager to develop the tool by adding several more menus serving as a foreign language menu, menus that can be used in physics and chemistry courses.

Participants' views on CP as an educational tool also indicated differences among the attitude groups. The common feature of CP that was mentioned in all of the three interview groups was visualization. Participants gave several examples from the classroom observations to explain how visualization provided them with some advantages. Visual representations in CP captured their attention and thereby enhanced their understanding of mathematics, took their interest, provided permanence, enabled them to compare numerous graphs, widened their point of view by sliding and tracing features, and provided construction of several shapes.

Different than the other two interview groups, in the third group, which was formed by the participants having highest attitude level, some aspects were identified about the GC in terms of its use in mathematics classrooms. The opportunities that CP serves such as multiple representations, the importance of teachers' experiences and capability on using the tool, and students' works on the tool leading them to research based learning were identified only in the third group.

When the place of CP in mathematics courses was considered, use of CP in problem solving and exercise part of the lesson was suggested in all of the three attitude groups. Pre-service teachers suggested that a teacher can prepare several CP integrated tasks and activities about a mathematical subject. They believed that



students would reinforce a mathematical subject more willingly by CP integrated tasks and that CP would provide save of time in classrooms by serving quick computations and operations.

Different than the other groups, in the third group, 5 participants suggested that a separate course where CP is used as the main tool would be beneficial for students. Participants named the course as an application course in which CP integrated tasks and activities would take place. In the application course, participants indicated that students would reinforce the mathematical subjects by working on CP activities. In addition, only in the third group it was suggested that students' use of CP should be permitted in the exams. In other words, students would use CP in assessment and evaluation parts of the lesson.

The content of CP in terms of the mathematical subjects was discussed during the classroom studies and interviews. The common idea of the participants in the three groups was that they, as teachers, would choose to use CP in graphing and geometry. They explained some reasons such as CP forms visual and accurate graphs and geometrical figures, gives the opportunity to compare more than two figures and graphs on the coordinate axis, and facilitates the discovery of figures by dragging and zooming functions. The easy and accurate sketching of graphs and drawing of the figures made CP more useful than paper and pencil in the teaching and learning of geometry and functions subjects. Apart from this common idea, participants in the second group suggested the use of CP in the subject patterns, and participants in the third group suggested the subject equalities and equations. It was observed that participants having higher attitude level towards technology and mathematics were more eager to use CP in the teaching of various mathematical subjects than the other two groups.

The third group was very interested in the tool and wondered whether teachers would let them use it in university courses. For pre-college level, they agreed in the idea that CP should be used after the first five grades or in secondary level. On the other hand, earlier use of CP was suggested in the first group. In the

first group it was suggested that, when integrated with paper and pencil, CP can be used in mathematics education in schools starting from the fourth grade.

Participants in the first and second groups expressed that they found CP more advantageous than paper and pencil in terms of the regular and correct drawings that CP serves and they believed that CP saves time in classroom studies. On the other hand, participants in the third group mentioned additional reasons for why they considered CP more useful than paper and pencil. CP serves comparison of more than two graphs, widens the user's view by providing zooming and dragging functions, and helps the user to remember some basic information about a mathematical concept.

Participants also considered the obstacles they might face as a teacher and the obstacles that elementary school level students might face when CP is used as a tool in classrooms. One participant from the first group complained about the management of the classroom when CP is used. She mentioned that use of CP as a main tool in mathematics courses would cause management problems in crowded classes. In the second group, there were additional claims that the training period of CP would produce problems in crowded classes. Participants mentioned that, in order to prepare students for efficient use of CP, teachers should provide an environment for students to gain experience during a required period of time. The participants of the second group pointed that difficulties in management of the classroom would occur in introducing students CP and teaching them how they would use CP for specific calculations.

In terms of the challenges that elementary school level students and teachers might face, participants of the third group did not mention any of the difficulties above but one. Two of them stated that CP might condition students for ready-made answers. Other views of the participants in the third group, in terms of the elementary school level students' use of CP were positive views such as CP provides verification, beneficial for talented students, make students like and deal with mathematics willingly, and provides quick and accurate calculations.

The views of the three groups showed an obvious difference in terms of the motivating effect of CP on students. The common ideas mentioned in all of the three groups were that CP has a motivating effect on students for the reason that the tool builds up passion and wonder. The first and second groups gave the reason that the tool is visual and enjoyable. Whereas, in addition to the visualization function of the tool the third group mentioned that CP is practical in use and easy to be managed which increased their motivation during the classroom studies. Participants in the third group made additional statements. One of them was that CP helps in recall as it has basic mathematical concepts in its content. Other idea was that CP would make students active in classroom environment and would encourage active attendance in mathematical tasks. The common idea among the three groups was that over use of CP would be boring for elementary students; therefore teacher inference is necessary.

When the overall observation period is considered, participants having higher attitude scores participated more in the classroom studies and they were eager to involve in the CP related tasks.

## **CHAPTER 5**

### **CONCLUSIONS, DISCUSSIONS, IMPLICATIONS AND RECOMMENDATIONS**

This chapter presents the interpretation of the results in brief in the conclusion part. Furthermore, the discussion and implications of the results in various fields are explained. In the last part, recommendations for future studies are presented.

#### **5.1 Conclusion**

Participants expressed their thoughts both with behaviors and words in four processes: training and instruction process, interviews reflecting on open-ended questions, and completing attitude scales. According to the analysis of these data sources, results are concluded in three main headings; use of the Classpad (CP) as a personal tool, use of CP as an education tool and the relationship between CP and motivation.

As a result of a qualitative study “researcher develops a theory or compares pattern with other theories” (Creswell, 1994, p. 96). Therefore, in this chapter, the patterns emerged in this study are compared with the previous studies in the related literature.

A quick and fast development in participants’ use of CP is observed during the instruction process and they also reported a “difference” between the first and the last days of the instruction process. As P20 expressed in the interview, in the first day of the training they were “hopeless” about how they will be able to use the menus that seemed them very “hard to understand”. The reason of lack of use in

some steps might be the short period of the use, but when the majority of the participants are considered, observations and interviews show that they get used to CP day by day, the problems they face decreased and their ability on using CP improved fast.

Although the instructor was always helping participants to find the related menu, necessary shiftings, and buttons, when the instruction period continued, participants' questions about finding direction in CP were decreased and they found answers to their questions by discovering CP themselves. For example, in a task, letter "b" was used as the variable for the unknown; in another task there was the letter "r" as the variable of strawberry jam quantity. In CP, there are four letters defined to be used as variables - x, y, z, and t - whereas the participants insisted on using letter "b" and "r" as it was told in the tasks. When CP did not except these letters as variables, they found the way to define all the letters as a variable in a short time in the same course hour without getting help from the instructor. In the following courses, it was observed that everyone was using the "changing variables" action without teachers' manipulation or guidance. By relying on the observed progress in participants' use of CP, it can be concluded that by discovering and exploring the tool, participants reached to anything they need in CP easily by themselves.

At the end of the analysis, data was grouped under three headings as mentioned above. Patterns showed a one within the other relationship between the three groups. Creswell (1994) explains this as:

"A theory may not be a 'container' because it does not fit a particular situation, or it inadequately explains what is occurring naturally in a situation. One needs to build a new theory by using an inductive model of thinking or logic. The researcher begins by gathering detailed information and forms categories or themes until a theory or pattern emerges." (p. 95)

There realized connections between the use of CP as a personal tool, the use of CP as an educational tool, and relationship between CP and motivation. This connection and the main categories emerged from the results of this study is

visualized in Figure 4. Although the results of the study were categorized in three main headings, pre-service elementary mathematics teachers expressed their views on each category depending on other two categories. For instance, while talking about their personal use of CP, they were also relying on the educational features of the tool and about how the tool motivates them.

In the classroom observations, researcher observed that pre-service teachers use CP in solving mathematical problems by assigning the tool different roles. At the end of the classroom studies, it was seen that participants considered CP as a tool that can be used in solving mathematical tasks. In addition, they considered CP more motivating than paper and pencil. Lastly, they mostly mentioned that they would like to use CP every time out of school that it provided them with wide range of mathematical subjects and increased their attention on mathematics. It was drawn from the views of the pre-service elementary mathematics teachers that, as in Figure 4, the three corners of the triangle exist concurrently when they used CP. In other words, when an educational tool also acts as a personal tool and motivating tool, students tend to use it more frequently and more willing. According to the pre-service elementary mathematics teachers, who participated in this study, CP covers all the qualities of an instructional tool which serves as a personal tool, educational tool and a tool that increases motivation.

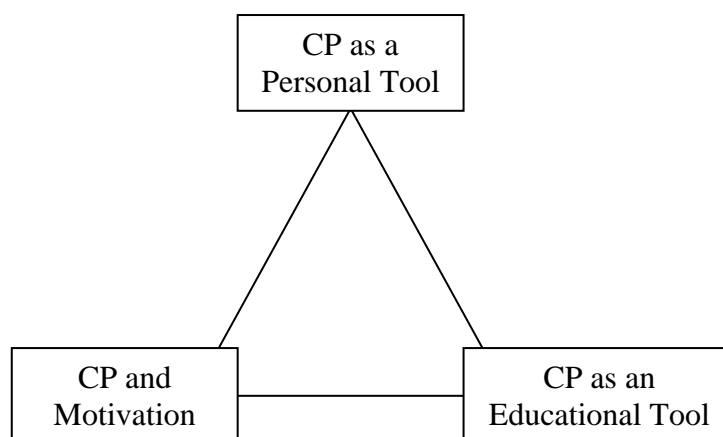


Figure 4. Three main categories

### **5.1.1 Use of CP as a Personal Tool**

The reason of forming the category ‘CP as a personal tool’ is that there were comments, ideas and views of participants in all data collection instruments which were about their experiences in the use of a technological tool regardless of considering it as just an instructional tool, instead; thoughts about their personal use when they deal with the tool in classroom, at home. Their personal thoughts were diverged into three contents; personal use of CP, physical features and technological equipment of CP, and menus, functions and content of CP.

Most of the participants showed and stated that they were enjoying the tool during the instruction process and therefore eager to learn more about CP. All of the participants needed guidance and help when it was their first time in using a menu. After getting assistance in the first use, they expressed that use of CP is practical and easy because “everything is already written” in it. Participants mentioned themselves as “incompetent” in the use of CP which they explained as that they feel “sufficient” only for the menus they had experienced through the instruction process. The general thought among the participants was; the better one uses CP, the more he benefits. Five participants mentioned that CP is important for any person deals with mathematics.

Seven of the participants who were interviewed stated that people around them showed interest on CP such as a high school student, a university student in economy, and another student in statistics department. They also mentioned that these people were able to use some of the menus of CP.

When the physical features and technological equipment of CP is considered, participants gave suggestions in terms of making additional features to CP such as, connection to internet, colorful cover, colorful screen, portable sliding keypad, a more lightened screen for night use, memory card, battery, and a speaker. It was an outcome that for the majority of the participants, touchpad took their attention and provided easy use. Oppositely, for some of them stylus caused problems, as it sometimes did not react which slowed the calculations. Participants consider CP as a

“beneficial” tool because it helps them make and fast, accurate and reliable calculations, solve equations and draw the graphs conveniently. More than half of them suggested that CP should be improved to show the calculation steps. For the content of the tool, all of the participants found it sufficient in terms of elementary grade mathematics content. In addition, 11 participants mentioned that CP has a full content for all grades of mathematics. 4 of them suggested content of CP be separated according to the levels and each subject be downloadable from internet.

Although it was a suggestion that the language of the tool should fully be translated to Turkish to provide comfortable use was made by only two of the participants during the interviews, the misunderstanding of English terms in the tool was frequently observed in most of the participants during the instruction process.

When the idea of adding other subjects such as physics and chemistry to CP was presented in group three, P3 made an explanation that shows the meaning of CP for her, for mathematics and how much she was impressed with a mathematical tool. It was specifically mentioned that CP includes both pre-college and undergraduate level mathematics subjects which the pre-service elementary mathematics teachers considered as an efficient tool for mathematics.

Among the 4 menus of CP which were frequently used in the four-week instruction process, the menus that the participants understood and used quickly and easily are the main menu, graphics and tables, and geometry. As the menu e-activity is the union of all the menus related to algebra, it was the most frequently used menu in the instruction process. Although during the instruction process 2 participants found the menu e-activity complex to use, majority of the participants were capable of using the e-activity menu at the end of the instruction period. This was an expected outcome because e-activity is a complex menu that combines all of the menus in CP and participants also mentioned this menu as “everything” and “very beneficial”.

The menu graphics and tables and the geometry menu are the other two menus that participants found beneficial and enjoyable. They mentioned the multiple



representations facility that these menus provide as effective. It can be clearly seen from the observations, interviews and open-ended questions that all of the participants were impressed about the graphing facility of the tool.

### **5.1.2 Use of CP as an Educational Tool**

An analysis of data about pre-service elementary mathematics teachers' views and thoughts on whether GCs are reasonable to be used in mathematics teaching and learning is documented in this section.

It was observed during the instruction process and verified in the interviews that interaction among the participants was increased when compared to the traditional CSE course when participants were working on the computers before the instruction period. Participants, when they had difficulty, were helping each other or recognizing their fault by looking at each other's CP screen before the teacher approached them. The interactions were observed both between participants and the instructor and among participants.

All of the participants were very interested in using CP both as a personal and as an educational tool. In addition, they all suggested the use of CP in mathematics education in schools. As they stated in the interviews, they had concerns about CP doing all the calculations and giving ready-made results to the user. There were other participants in the first and second groups who shared this concern. As a solution of these concerns, participants suggested the partly use of GC in lesson plans. They released the students getting used to ready-made calculations risk by suggesting the use of CP in the particular parts of the lesson.

When the interviewed participants specified the appropriate parts of a mathematics course that CP should be used to be effective, they referred to problem solving (12 participants), exercise (12 participants), warming-up and reminding (3 participants), assessment and evaluation (3 participants) parts of a lesson. Some of them (7 participants) suggested a separate course where CP is used as the main tool to do problem-solving exercises of mathematics subjects.

As the participants suggested the use of CP in specific parts of a lesson, they also specified the mathematical subjects that CP would be an appropriate tool to be used in the teaching and learning period. For the use of GCs, mostly referred and suggested subject is functions and graphing. This was an expected outcome as graphing and functions is the subject of an extensive research (Lloyd & Wilson, 1998; Simmt, 1997; Hennessy, Fung, & Scanlon, 2001; Lauten, Graham, & Feerini-Mundi, 1994; Ruthven, 1990; Schwarz & Hershkowitz, 1999) about use of GCs in mathematics education. CP use in geometry was also suggested by 12 participants. For using CP in learning and teaching of geometry, they expressed several reasons such as the menu geometry is visual, takes attention and easy to use. CP use in patterns and equations in elementary grade was also suggested.

Participants discussed their concerns about use of CP both as a student and as a pre-service teacher. They argued about elementary grade students' use of CP and the most common idea was that students should be capable of using CP in order to understand the aim of the tool and use it effectively through the courses.

According to the expressions of participants during the observation period and interviews, use of CP as an educational and a personal tool in elementary level was recommended by 18 participants. As elementary level is the first 8 years of the education period in Turkey, participants suggested students start using the tool either in grade 4 or in grade 6. Rest of the participants recommended CP use in secondary grade and at university in higher level mathematics. Moreover, as the participants were in a mathematics-based department, they were very willing to use the tool in their remaining three years at university.

Participants liked the tool, they defined it as beneficial, but they have concerns about how to adapt CP to Turkish elementary mathematics curriculum and how to teach CP use to elementary level students. The common idea was that CP use in mathematics classrooms should be integrated with paper-pencil.

Comparing CP with paper-pencil took place during the instruction process, in the answers of the open-ended questions and in the three focus group interviews.

Almost all of the participants emphasize the correct, regular and scaled drawings in graphs and geometry. Other advantages of CP mentioned were serving the user a wider view, helping the user to remember any mathematical knowledge, and saving files in its memory.

### **5.1.3 CP and Motivation**

It was mentioned in the interviews, in the answers of the questionnaire by the participants, and was observed during the instruction process that participants were impressed with using a GC during the algebra instruction. In general, they compared CP with traditional education that is mostly instructed by using paper-pencil. They added that, CP took their attention and all of the participants expressed this many times. Their attention grew up every time they learned more about the tool.

All of the participants in the first group and some of the participants from the third group expressed their willingness in joining the instruction process of CP, which shows a high motivation. Although only 10 participants in the interviews directly mentioned their volunteering participation to the classroom studies, it was seen during the interviews that all of the participants in the study were joining the courses in enthusiasm as they had mentioned it very often during the courses and in the breaks.

Majority of the participants in the three interview groups stated that CP builds up one's interest and curiosity in any level and task. Participants made statements in three ways, from their own point of view, from elementary and secondary grade students' point of view and from other people's point of view that are not educators or students. From their point of view as pre-service elementary mathematics teachers, participants considered their usual habits while learning mathematics with paper and pencil. They mentioned that CP increased their curiosity and interest on mathematics by giving immediate feedback. In addition, with CP, they mentioned that they did not have the obstacles they faced with paper and pencil such as irregular sketching and calculation mistakes that caused waste of time. From pre-college

students' point of view, because of being a technological tool, covering many subjects in mathematics, practical in calculations, and providing multiple representations with visualization; students would be eager to do their homework on CP, would like to solve different problems quickly and practically, and work on CP longer than they study with paper and pencil. Moreover, it was frequently mentioned that CP would increase active participation to courses and encourage competition between peers which would last in increase in learning. From other people's point of view, a technological, visual and practical tool full of mathematical menus, and other menus such as presentation, would make people get one CP for themselves.

On the other hand, participants had some concerns about the use of CP in mathematics classrooms. Some of them doubted that there would be decrease in motivation when students use CP too often during the courses; therefore they would quit studying with the tool. Another concern was that students who can not use CP comfortably and lacks information about the needed functions to solve a problem, he would quit working on the problem. This would decrease students' motivation on learning mathematics and participation to the course. As a solution to these doubts that pre-service teachers mentioned, they suggested the teacher manage students' use of CP during the courses. In other words, teacher should get the responsibility to decide where and in which subject the use of the tool will enhance learning.

## **5.2 Discussions**

In this section, pre-service teachers' views on the use of CP in mathematics education for mathematics teachers, students, and curriculum developers are discussed. When the results of the present study are reviewed, it can be stated that learning how to use a GC in university education, especially starting from the first year, can make contributions to develop effective skills for pre-service elementary mathematics teachers. Pre-service teachers mentioned some advantages of using CP in learning and teaching of mathematics. These advantages can be listed as; helps to save time, provides multiple representation and transformation between graphical

and algebraic expressions, sketches correct and accurate drawings, provides easy and quick calculations, has a broad content to discover mathematics. In concordance with these advantages, Özgün-Koca (2009) found that pre-service teachers emphasized the transformation, time saver, computation, and discovery roles of GCs. In addition to these roles mentioned Özgün-Koca (2009) where the views of pre-service mathematics teachers on the use of GCs in mathematics education were reported, participants of the existing study mentioned the motivating effect of CP for its features of being visual, enjoyable, practical, attention taking, building up passion and wonder, and leading to competition.

According to their use in the classroom studies and statements from the interviews, the roles that pre-service elementary teachers denoted to CP in the present study can be listed as a checking tool (Dahland & Lingefjard, 1996; Forster & Mueller, 2001) and a computational tool (Dahland & Lingefjard, 1996; Farrell, 1996; Forster, 2000; Özgün-Koca, 2009) which they used the calculator for checking or confirming their numerical and algebraic work, made calculations with high digit numbers; a visualization tool (Dahland & Lingefjard, 1996; Hennessy, et al., 2001; Özgün-Koca, 2009) where they sketched more than one graph of the equations and compared them easily, realized patterns accurately and clearly; a transformational tool when they wrote the equation of a problematic situation and transformed that information into graph and saw the equations' variable table quickly and saved time; a discovery tool (Özgün-Koca, 2009) where they felt as they were the constructors of the solution process which they progress with the help of their own ideas independently. With these various opportunities that CP serves, the tool motivated the users to work more than they were assigned to. As Ersoy (2005) states, instructional technologies and GCs are the supportive tools to make the students like learning mathematics. In the existing study, most of the participants tried other solution ways when they completed the assigned task and were waiting for others to complete, rather than leaning back and resting. It was recognizable during the classroom observations that participants were interested in using the tool.

Participants sketched the graph of an equation occurred from a problem in lesson 3 and they were asked to explain the difference in the graph of the equation when the number of the jam bottles increases. Participants were observed that they made more than two trials by giving different numbers to the variable  $x$ . Then it was observed that they sketched the equation by changing the coefficient of the variables  $x$  and  $y$  and investigated the change in their graphs. Further, participants during the classroom studies used the time left from the tasks to explore the tool, to discover its features and tried to use the tool in different mathematics subjects rather than algebra. In addition, what led participants to work on anything that they wonder was the quick work and immediate feedback that CP provided. When the results of the existing study and literature findings are considered, in teacher education, pre-service teachers should have the opportunity to experience with GCs in order to explore their advantages in mathematics education.

Similar to the views of pre-service teachers in this study, visualization feature of GCs was also revealed as a result of the study that Hennessy, et al. (2001) conducted with open-university students. Another crucial role that pre-service teachers mentioned was the multiple representation and transformation advantage that CP served while working on the algebraic tasks. Participants expressed that they had the opportunity to see the relationship between the equations, their value table, graphs of the equations, and emerging patterns concurrently. The other advantage was that GC filled the gap occurred from the lack of knowledge of connecting symbolic and graphical representations.

Another result that can be considered as an advantage for both student use and teacher use of the tool in classroom, which is also mentioned by Hennessy, et al. (2001), Kastberg and Leatham (2005), Mesa (2008), and Roschelle and Singleton (2008), was that students had the opportunity to test more functions of a given mathematical situation and work on various concepts in the same amount of time that they work for one question with paper and pencil.

It was evident during the classroom observations that as the experiences of the pre-service teachers increased, their aptitude towards using GCs in mathematics education also increased. Participants, during the interviews, also mentioned that the more they used CP, the more they benefit from the tool (Heller & Curtis, 2005). Therefore, it can be suggested that pre-service elementary mathematics teachers should use GCs in their university education in mathematics related courses starting from the first grade. In fact, the GC CP has a broad content to be used in the department of Elementary Mathematics Teaching, in the courses such as, in the first grade General Mathematics, Concrete Mathematics, Geometry, Computer Supported Education (CSE); in the second grade Analysis I and II, Linear Algebra I and II, Physics I and II, Teaching Technologies and Material Design; in the third grade Analysis III, Analytical Geometry I and II, Statistics and Probability, Introduction to Algebra, Special Education Methods I and II, Differential Equations, Complex Analysis.

Considering the results of the use of GCs as an educational tool, participants regarded the connection facility of CP with computers as an advantage for the users - both teachers and students – in classroom environment. In addition to the connection with computers, program download was also suggested if CP will be improved in the future. In this study, instructor used her CP from the computer and its screen was always on the board during all of the courses. Similar to CP in the existing study, a connectivity software and GCs were used as the main tools in the research that Robutti (2009) conducted. Having formed an environment both with GCs and connectivity software, the researcher observed signs in construction of knowledge where the latter provided social interaction leading a way to learning community. In addition, it was found that connectivity software enhanced active participation of the students and increased interaction between students in classroom environment because it provided students and the teacher to show their work to each other. The results of the present study confirm Robutti (2009) that the connection of CP with computers lead to active participation of students to the algebraic tasks and this

enhanced pre-service teachers' construction of mathematical concepts, specifically algebra concepts.

Current educational theories emphasize active involvement of students in teaching-learning process. A common result of some studies state that GCs stimulate students' active involvement to the courses and work on the activities willingly both as students and task setters (Drjvers & Doorman, 1996; Harskamp, Suhre, & Streun, 1998). Similarly, in this study during the classroom observations, participants seemed more willing and interested in the tasks where the GC CP was used as the main tool; they enjoyed to work together and reflected to questions willingly, were helpful to each other when one could not find a function on CP, and eager to construct the tasks over again by giving advices to the instructor as they were teachers although they were not asked to. It was observed during the classroom study of five weeks that all of the participants showed active involvement to the process without showing any hesitation to the GC integrated elementary level tasks. Everyone participated to classroom discussions where solution strategies to tasks were discussed. Owing to active participation, it was observed that understanding of algebra tasks and features of CP was improved.

Moreover, as the participants of the present study were pre-service elementary mathematics teachers, their visions of teaching elementary level algebra by using a qualified technological tool – Casio Classpad 330 grew up in end of the instruction period. As some of the participants mentioned in the interviews, when elementary level education was considered, CP facilitated learning of patterns, enabled to express algebraic equations in different ways such as graphing and solving numerically. By having more experience on using the tool, pre-service elementary mathematics teachers can use the tool to enhance their mathematical knowledge and be more qualified teachers in the future. Heller and Curtis (2005) conducted a study with high school students and their teachers and found that students whose teachers were trained and more experienced in using GCs, had higher marks in the algebra achievement tests. By considering the literature and results of



the existing study, experienced pre-service teachers will be more beneficial to their students in the future and will be more productive in terms of teaching skills in elementary level mathematics.

Apart from their use in mathematics classrooms where GCs serve as public tools, they also serve as private tools (Robutti, 2009) where students can have their free working area and study on mathematical subjects by themselves. Pre-service teachers considered CP as a personal tool which they explained as a necessary and important tool for a mathematician. That is to say, they regarded the personal benefits of CP as an assisting tool that pre-service teachers can use in most of their courses at university level and out of school whenever they would like to deal with mathematics according to their personal interest in mathematics.

Moreover, the easy use of CP was a factor in pre-service teachers' positive aptitudes towards CP. In the existing study, 19 out of 21 of the participants were confidently using four of the menus in CP at the end of the instruction process. The quick learning period and easy use of the GCs was also mentioned in several studies that focus on the learning period of the students who experience GCs for the first time (Burrill et. al., 2002; Ersoy, 2006; Özgün-Koca, 2009, 2010)

As opposed to the four menus of CP, spreadsheet menu was misunderstood by two participants. One participant explained the reason of the misunderstanding in this menu as the screen shows only a small part of the main table which leads difficulty in controlling and therefore understanding the data on the table. Another reason of the difficulty that participants faced in using the spreadsheet menu can be that only one task was conducted with that menu.

### **5.3 Implications**

Developing mathematical problem solving skills and teaching students to construct mathematical knowledge are the basic aims in mathematics education (NCTM, 2000; MEB, 2005). Mathematics education should be integrated with advanced and interactive technological tools. Technological tools such as

spreadsheets, GCs, dynamic graphing tools, computer algebra systems, dynamic statistical packages, data collection devices, and presentation software are considered as essential to be used in teaching and learning of mathematics (NCTM, 2000). However, using technological tools in education such as GCs do not guarantee the students to be a mathematics literate. GCs can only help students to concentrate on mathematics, provide motivation in mathematical activities, and enhance problem-solving skills (Ersoy, 2005). Therefore, using GCs should not be the aim of mathematics courses; they should rather be used effectively as instructional tools.

In NCTM (2000) program standards for middle school mathematics teachers, use of technology is in the standard list of knowledge of mathematics pedagogy for initial preparation of mathematics teachers. Expectations from teacher candidates include “developing lessons that use technology’s potential for building understanding of mathematical concepts and developing important mathematical ideas” (p. 4). Parallel to the recommendations of NCTM, results of the existing study reveal several suggestions for elementary mathematics teachers about the use of GCs effectively as instructional tools in elementary mathematics teaching and learning. Specifically, if the use of CP is considered as an instructional tool in pre-college level mathematics, there are important points that pre-service teachers emphasized for GC use in classroom applications. Firstly, for the lessons in elementary level mathematics, CP should be integrated with paper-pencil. As Ersoy (2005) stated, pre-service teachers mentioned that using instructional technologies is not the only way to learn and teach mathematics; rather instructional technologies and GCs are the supportive tools to like learning mathematics. In addition, tasks and activities in the lesson plans, where GCs will be used, should be properly prepared according to the subject of the lesson. In this study, pre-service elementary mathematics teachers mentioned that the way students use the tool and the role they assign to a GC should not only be for computation; rather they should be able to use GCs effectively. Teachers’ arrangement on the technology integrated lesson plans and tasks is crucial as they should lead the students to understand the actual aim of the tool and provide

environment to make the students be capable of using the tool. In other words, as Burrill et al. (2002) remarked, teachers should allot an adequate time for the training period of students on the use of GCs. These suggestions meet the goals of NCTM (2000) and MEB (2005). In the principles of NCTM (2000), it is emphasized that learning of mathematics will occur more deeply if the use of technology is constructed appropriately. Similarly, in MEB (2005), calculators are suggested to be used starting from elementary mathematics education but not for all calculations or during the course. Second suggestion for teachers' use of technology in mathematics classroom is that GCs can be used in the problem solving processes, exercises, and activities during the courses; also in the warming, reminding, and assessment parts of the lesson plans. Thirdly, according to the pre-service elementary mathematics teachers in this study, with its features of providing multiple representations, visualization, immediate feedback, broad content, and sixteen menus, CP is qualified enough for all the learning areas of pre-college mathematics. Therefore, CP can be integrated to almost all of the mathematical subjects in elementary and secondary level. Proving this outcome, there are a number of studies in elementary level and in secondary level (Burrill et. al., 2002; Roschelle and Singleton, 2008) focusing on the teaching of subjects such as algebra, geometry, functions, trigonometry and numbers with GCs.

In addition to pre-college level education, pre-service elementary mathematics teachers recommend the use of GCs in university level by integrating calculator use to mathematics related courses. They believe that a GC will assist them in courses such as General Mathematics, Concrete Mathematics, Geometry, Analysis, Algebra, Physics, Teaching Technologies and Material Design, Statistics and Probability, Differential Equations, and Computer Supported Education (CSE) in their university education. They also suggested that, university education should provide pre-service teachers the opportunity to explore the role technology can play in helping them achieve their instructional goals; learn mathematics with a technology integrated program. If they construct mathematical concepts in the

courses engaged with GCs, they will see the benefits of technology in their education and they will be able to reflect these benefits to students when they become teachers (Alagic & Palenz, 2006; Burrill, et al., 2002). This will lead them to use technological tools such as GCs in mathematics classrooms willingly. Therefore, for pre-service mathematics teachers, to experience the role of technology in mathematics education more, technological instructional tools should be integrated to university courses.

Mathematics teachers can benefit from the views of pre-service elementary mathematics teachers in this study, in terms of integrating GCs into mathematics education. According to the views of pre-service teachers, CP is easy to learn, fun, practical with its touchpad screen, has a broad content, serves mathematics integrated menus, includes menus such as e-activity which provides several functions to prepare tasks, activities and worksheets that combine various mathematical subjects. For all these reasons using CP is beneficial for teachers' professional development in their jobs. Furthermore, CP is beneficial for teachers and teacher candidates to develop themselves in mathematics. In this study, it was expressed by pre-service teachers that CP is a tool to be used personally for the ones who want to deal with any subject of mathematics whenever they want and need to and it was also mentioned that every mathematician should use a GC. Various studies also recommend teachers to experience GCs in order to develop themselves in high level mathematics (Roschelle and Singleton, 2008) and also create tasks in pre-college level mathematics (Burrill et. al., 2002) with the help of GCs. In specific, for classroom use of CP in elementary level algebra, the content and menus of CP is sufficient as the tool includes main menu for the calculations algebraic expressions, geometry menu for patterns and relations, graphs and tables menu for equations and graphs of the equations, and e-activity menu to perform tasks that combine all of the sub learning areas of elementary level algebra. So as Roschelle and Singleton (2008) remarked, newly produced GCs are appropriate for the subject algebra in terms of their content and

menus; GCs have a positive effect on the learning of algebra and students' progress on algebraic concepts.

Lesson plans prepared for the classroom studies of the existing study can serve as examples for the elementary mathematics teachers who are willing to use GCs in their classrooms. Curriculum developers can benefit from the detailed lesson plans to see examples of integrating GCs to different parts of a lesson plan such as warming, reminding, teaching and learning period, application and assessment, in the teaching of elementary level algebra. To use GCs as instructional tools in elementary level mathematics education, it can be suggested that curriculum developers and test makers prepare tasks and activities that can be conducted with the use of GCs.

#### **5.4 Recommendations**

The present study indicates the views of pre-service elementary mathematics teachers on the use of a GC – CP – in mathematics education. Their views were grouped in three categories. Participants considered the tool in three headings which are as a personal tool, as an educational tool and the relationship with the tool and the users' motivation.

The existing study might be replicated by adding achievement scores of the participants to the existing data. An achievement test in the related subject can be given as a pre-test or both as a pre-test and post-test. In a study of this kind, the qualitative data will be supported with the quantitative data. An achievement test that requires GC use will provide the researcher to understand the familiarity and usage level of the participants with the tool, how efficient they are with the content of the tool, and see if the instruction period is long enough for the teaching and learning of the related subject with a GC.

When the results of the study are reviewed, there is data about the four menus of CP which are main menu, graphics and tables, e-activity and geometry. It can be recommended to conduct a study with one of the menus of CP with detailed lesson plans that only focuses on one menu. In an instruction period similar to the one in

this study, all functions of one single menu can be investigated deeply with leading tasks. According to the results of that study, the tool can be advanced with all its menus and functions to be used as an instructional tool in mathematics courses permanently.

Similar to focusing on one menu, researchers can focus on one subject of pre-college level of mathematics, which is algebra in the existing study. When a sufficient number of study is conducted on elementary level subjects, there can be strong recommendations about where to use CP in the learning and teaching of every mathematics learning area. These studies will guide elementary mathematics teachers in developing teaching skills and preparing lesson plans with GCs.

Another study can be designed with the other menus of the tool which are 3D graph, conics, geometry, number solve, and e-activity with the same method design of this study in secondary level mathematics with the pre-service secondary mathematics teachers.

Classroom applications of pre-service mathematics teachers, who are trained in the use of GC during their university education, can be investigated. Pre-service teachers' compulsory course which is school experience in the fourth year of the university education and their first year when they become teachers can be observed to see how and in what ways they use technology, especially GCs, in their classroom, to investigate the roles they assign to calculators, and observe the tasks they prepare.

In this study, pre-service teachers were grouped in three, according to their scores from teaching algebra with technology attitude scale, mathematics attitude scale and technology attitude scale. The difference between the groups can be investigated deeply, in order to see the long-term effects of technology-integrated education. Pre-service teachers' attitudes in their first year at university were obtained in this study. Following this, the change in their attitudes can be investigated during the four years of university education. This would provide the researchers to see how technology based education reflect on attitude. In addition,

technology effect on pre-service teachers' attitudes, their views on the place of GCs in mathematics education can be investigated.

For the new productions of GCs, CP is considered to be a sufficient and high technological tool as its menus not only comprise related features and functions to make mathematics in undergraduate and pre-college level, but also includes other menus such as presentation, data collection and analysis. As a mathematical tool, the menu e-activity is very functional as it brings all of the menus together which is used to form challenging tasks in mathematics that combines different subjects. In addition, CP is a way high standard tool with its physical features and technological equipment such as the touchpad screen, easily manageable dimensions, data transfer with CP and computer connection. In order to develop a more functional tool, it can be suggested to add internet connection, colorful screen, sliding keypad, memory card, video camera; menus can show calculation steps; menus can be separated according to grades such as sixth grade subjects and be downloadable when needed. In addition, adding menus such as language, physics, and chemistry can make the tool be also used in other fields, too.

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## APPENDICES

### APPENDIX A

#### LESSON PLANS

##### Ders Planı I

**Sınıf Seviyesi:** 6. Sınıf

**Süre:** 50+50 dakika

**Öğrenme Alanı:** Cebir

**Alt Öğrenme Alanı:** Cebirsel İfadeler

**Kazanımlar:**

1. Belirli durumlara uygun cebirsel ifadeyi yazar.

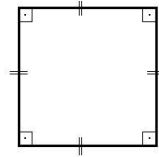
##### Öğretme Öğrenme Süreci

**Hatırlatma:**

Öğrencilere geçmişteki örüntü bilgilerini hatırlatmak için aşağıdaki örnekler verilir:

Halı desenleri, merdiven basamakları.

**Isındırma:**



- “Şekildeki karenin bir kenarı 5, 6, 7 ... cm ise çevresi kaç cm dir?”
- “Nasıl buldunuz, hesapladınız?”
- “Kenar uzunluğu değıştikçe hesaplarınızın nasıl değıştiğini gösteren bir tablo oluřturunuz.”
- “Kenar uzunluğu bilinmeyen bir karenin çevresini nasıl belirtebiliriz?”

benzeri sorular öğrencilere yöneltilir.

Kenar uzunluğu değıştikçe karenin çevresini nasıl hesapladıklarını, nasıl ifade ettiklerini fark etmeleri için, farklı kenar uzunlukları verilen karelerin çevrelerini hesaplamaları istenir. Böylece genel bir çevre formülüne ihtiyaç hissettirilir. Öğrenciler arasında karenin çevre hesabı için “4a” cevabını veren olursa, öğrencilerin akıllarındaki soru işareti ile merak ile derse geçiş sağlanması için doğru cevap belirtilmez. Öğrenciler doğru sonuca dersin sonunda ulaşmış olacaklardır.

### **Derse Giriş:**

Örnek Durum: Emre’nin hikaye kitaplarının sayısı Duygu’nun hikaye kitaplarından 6 tane fazladır.

Verilen duruma göre, öğrencilerden Emre ve Duygu’nun kitap sayılarının bir tablosunu oluşturmaları istenir. Emre’nin kitap sayısı 1 den itibaren artırılarak ilerlenir. Son adımda ise Emre’nin kitap sayısı “e” ile gösterilir ve öğrencilerin Duygu’nun kitap sayısı olarak “e+6” ifadesine ulaşmaları beklenir.

### **Etkinlik Planı**

**Öğrenme Alanı:** Cebir

**Alt Öğrenme Alanı:** Örüntüler ve İlişkiler

**Kazanım:**

1. Sayı örüntülerini modelleyerek bu örüntülerdeki ilişkiyi harfle ifade eder.

## Öğrenme Öğretme Süreci

Yeni evli bir çift evlerini salonları düzgün beşgen olacak şekilde tasarlıyorlar. Ortadaki beşgen evin salonunu temsil etmek üzere, salonun her duvarına komşu olan 5 adet beşgen şeklinde oda yaptırılmıştır. Bu odalar evin beyine aittir. Erkeğin odalarına komşu olarak yapılan 5 oda ise eşi olan bayana aittir. Bayanın odalarına komşu olan odalar ise çiftin yeni doğmuş kızları için yaptırılmıştır. Evde yaşayacak olan ailedeki her birey için bu şekilde odalar inşa edilmiştir.

Öğrenciler 2 kişilik gruplar halinde aşağıdaki soruları cevaplandırmak için çalışırlar.

- Evdeki kişi sayısı 4 olursa oda sayısının kaç olacağı sınıfta tartışılır.
- 4 kişinin yaşadığı bu evin modelinin çizilmesi istenir.
- Evde 5, 6, 7... kişi yaşarsa oda sayısı kaç olur?
- Oda sayısının kişi sayısı ile bağlantısını araştırınız.

Öğrencilerden aşağıdaki tabloyu tamamlamaları istenir.

Kişi sayısı	Salon + Oda sayısı	Toplam oda sayısı
1		
2		
3		
4		

Öğrenciler, her adımı matematiksel olarak ifade ettikten sonra genel kurala sözel olarak ulaşmaları için aşağıdaki adımla devam edilir. Genel kurala ulaşmak için sınıf içi fikir alışverişi yapılır. Öğrenciler düşüncelerini sınıfa açıklar. Genel kurala sözel olarak ulaşıldığında, öğrenciler oluşturdukları tablo yardımıyla örüntünün genel kuralının cebirsel ifade ile gösterimini oluşturur. Öğrenciler buldukları cebirsel ifadeyi grafik hesap makinesine yazarlar. Diğer gruplarla makineleri değiştirerek yazdıkları ifadelerdeki farklılıkları tartışırlar. Aile 42 kişi olursa oda sayısı kaç olur? sorusu grafik hesap makinesi kullanarak bulunur.



**Ölçme Değerlendirme:**

Aşağıdaki durumları cebirsel olarak ifade ediniz. Cebirsel ifadeleri grafik hesap makinesine yazınız. Bilinmeyenleri “a” ile gösteriniz.

- Bir sayının karesinin 5 katı
- Bir sayının 1 eksiğinin 8 katı
- Bir sayının 3’e bölümünün kendisi kadar fazlası

## Ders Planı II

**Sınıf Seviyesi:** 6. Sınıf

**Süre:** 50+50 dakika

**Öğrenme Alanı:** Cebir

**Alt Öğrenme Alanı:** Örüntüler ve İlişkiler

**Kazanımlar:**

1. Sayı örüntülerini modelleyerek bu örüntülerdeki ilişkiyi harfle ifade eder.

### Öğretme Öğrenme Süreci

**Hatırlatma:**

Öğrencilere geçmişteki örüntü bilgilerini hatırlatmak için aşağıdaki örnekler verilir: Halı desenleri, merdiven basamakları,

Örnek Durum: 3, 6, 9, 12, ... şeklinde devam eden sayı örüntüsü.

- Öğrencilerden bu örüntüye uygun model oluşturmaları istenir.
- Bir sonraki sayı bulunur.
- 7. ve 8. sayı kaçtır?

Adım sayısı ve her adıma karşılık gelen sayıyı gösteren aşağıdaki gibi bir tablo oluşturulur, tablo öğrencilere doldurulur. n. adımdaki sayı tabloda buldurulur.

Adım Sayısı	Adıma karşılık gelen örüntüdeki sayı	Örüntü ile model ilişkisi
1. adım		
2. adım		
3. adım		

En az bir bilinmeyen ve işlem içeren ifadeler cebirsel ifadelerdir. Cebirsel ifadelerde kullanılan ifadeler sayıları temsil eder ve “değişken” ya da “bilinmeyen” olarak adlandırılır.

### **Etkinlik Planı**

Kenarları 10 kareden oluşan şekle yüzlük kare denir. Yüzlük kareden artı işareti şeklinde 3 alt alta ve 3 yan yana (3x3 lük) olmak üzere bir sayı dizisi seçilir ve iki koldaki (yatay ve dikey) sayıların toplamaları karşılaştırılır. Öğrencilere örnek bir yüzlük kare ve bu kareden seçilmiş 3x3 lük sayı dizisi gösterilir. Bu etkinlik bir örüntü keşfetme çalışmasıdır.

Öğretmen etkinlikle ilgili olarak aşağıdaki bilgileri öğrencilere verir.

- Karenin şeklinin nasıl olabileceği konusunda öğrencilerin yönlendirilebilmesi için öğretmen, sınıfça öğrencilerin fikirlerini belirtmelerini ister. Bu aşamadan sonra öğrencilerin etkinlik üzerinde çalışmaları başlamış olur.

Her öğrenci sayısal tabloda kendi yüzlük karesini oluşturur. Sınıfça çalışıp fikir alışverişi yaparak artı (+) şeklinde alacakları sayı gruplarını seçerler. Seçtikleri sayı gruplarının yatay ve dikey toplamalarını akıldan ya da kağıt kalem kullanarak hesaplarlar. Öğrenciler grafik hesap makinesinin sayısal tablo menüsünde çalışırken toplam formülünü kullanarak birçok sayı grubunun kollarının toplamını kısa sürede bulup karşılaştırabilirler.

Öğrencilerin keşfetme sürecini kolaylaştırmak için sayısal tabloda boş bir kısma, yüzlük kareden seçecekleri artı (+) şeklindeki sayı gruplarından bir tane oluşturmaları istenir. Aşağıdaki soru sınıfa yöneltilir.

- Sayı grubunun ortasındaki sayı ile çevresindeki sayılar arasında bir ilişki var mıdır?
- Öğrencilere, 3 tane daha sayı grubunu, sayısal tablonun boş kısımlarında oluşturmaları söylenir. Aynı soru üzerinde tekrar düşünceleri istenir.

Sayılar arasındaki örüntü bulunduğunda, öğrencilerden bir sayı grubunun ortasındaki sayıyı yazdıklarında kollardaki diğer dört sayısında oluşması için bir

formül bulmaları istenir. Genellemeye gidilen bu adımda, yönerge öğrencilere aşağıdaki gibi verilebilir:

- Ortadaki sayıya  $x$  dersek kollardaki sayılar nasıl ifade edilir?

Öğrenciler ikili olarak yanlarında oturan arkadaşları ile çalışır. 10 dakika süre verilir. Öğretmen öğrenciler arasında dolaşarak aralarındaki fikir alışverişlerini takip eder. Çözüm yolu öneremeyen öğrencileri yönlendirir. (problemi tekrar açıklar, öğrencilerin takıldığını düşündüğü yerleri açıklar, çözüm yolu için bir adım gösterir vb.) Öğrenciler verilen problem üzerinde 10 dakika çalıştıktan sonra sınıf bir arada çözüm yollarını tartışmaya yönlendirilir. Öğretmen yönlendirici sorular yardımı ile sınıf içi çözüm paylaşımını ilerletebilir.

Öğrencilerden buldukları örüntüleri sınıfla paylaşmaları istenir. Çözüm ve öneriler sınıfça tartışılır.

Bulunan örüntünün, tüm sayılarda geçerli olabilecek genel bir formül olduğu vurgulanmalıdır. Bunun için, örüntünün yüzlük kare dışına çıkıldığında da geçerli olup olmadığı öğrencilere sorulur.

Daha sonra öğrencilere başka bir durum açıklanır. Bir matematik öğretmeni bu etkinliği yıllarca derse girdiği sınıflarda öğrencileri ile uyguladıktan sonra artı (+) şeklindeki sayı grupları üzerinde çalışmaktan sıkılmıştır. Öğretmenin öğrencileriyle üzerinde çalışabileceği yeni şekiller bulunması gerekmektedir. Artı şeklindeki sayı gruplarında bir sayı yazıldığında diğerleri bulunabildiği gibi, yeni bulunacak şekillerde de tek bir sayı yazıldığında şekli oluşturan tüm sayılar bulunabilmelidir.

Bu görev, öğrencilerin üzerinde bir süredir çalıştığı örüntü konusundaki tüm bilgilerini kullanarak sayılar arasındaki ilişkileri araştırmaya yönlendirir. Bu çalışma sırasında, öğrenciler grafik hesap makinesinin sayısal tablo menüsünde işlemlerini kolaylaştıracak özellikler kullanırlar.

### Ders Planı III

**Sınıf Seviyesi:** 6. Sınıf

**Süre:** 50+50 dakika

**Öğrenme Alanı:** Cebir

**Alt Öğrenme Alanı:** Örüntüler ve İlişkiler

**Kazanımlar:**

1. Doğal sayıların kendisiyle tekrarlı çarpımını üslü nicelik olarak ifade eder ve üslü niceliklerin değerini belirler.

#### Öğretme Öğrenme Süreci

$$3 \quad 3^1$$

$$3 \times 3 \quad 3^2$$

$$3 \times 3 \times 3 \quad 3^3$$

$$3 \times 3 \times 3 \times 3 \quad 3^4$$

$2 \times 2 \times 2 \quad 2^3$  benzeri örneklerle üs kavramı ile sayılar arasındaki ilişki gösterilir.

$a^n=b$  genel gösteriminde “a” ya taban, kaç tane a’nın çarpıldığını belirten sayı olan “n” ye kuvvet veya üs, ve “b” ye de değer adı verilir. a üssü n veya a’nın n. kuvveti şeklinde okunduğu belirtilir.  $27^1$ ,  $27^2$ ,  $27^3$  ve  $2^{27}$  üslü sayıları grafik hesap makinesinde hesaplanır.

$10^{10}$  sayısı kaç basamaklı olabilir? Sınıfça tartışılır. Grafik hesap makinesi ile kontrol edilir. Makinede,  $10^9$ ,  $10^8$ ,  $10^{12}$  sayıları hesaplatılarak basamak sayıları bulunur.

## Etkinlik Planı

**Öğrenme Alanı:** Cebir

**Alt Öğrenme Alanı:** Eşitlik ve Denklem

**Kazanım:**

1. Eşitliğin korunumunu modelle gösterir ve açıklar.
2. Denklemi açıklar, problemlere uygun denklemleri kurar.
3. Birinci dereceden bir bilinmeyenli denklemleri çözer.

## Öğrenme Öğretme Süreci

Aşağıdaki tablo sınıftaki öğrencilere verilir. İlk sütuna seçilen sayı ile adım adım yapılan hesaplar yazılır. İkinci sütuna ise her adıma karşılık gelen cebirsel ifade yazılacaktır, bu sütun grafik hesap makinesinde oluşturulur.

	I. Sütun	II. Sütun
Adım I	Aklından bir sayı tut	
Adım II	5 ekle	
Adım III	2 ile çarp	
Adım IV	6 ekle	
Adım V	12 çıkar	
Adım VI	2'ye böl	
Adım VII	Bulduğun sayıdan baştaki sayıyı çıkar	
	I. Sütun	II. Sütun
Adım I	Bir sayı düşün	
Adım II	7 ekle	
Adım III	10 ile çarp	
Adım IV	5'e böl	

Adım V 14 çıkar

Adım VI 2'ye böl

Cevabı, problemin başında tuttuğunuz sayının 3 katı olan bir problem oluşturunuz, probleminizi sınıfla paylaşınız.

Aşağıdaki soruları vererek öğrenciler arasında sınıf içi yarışma düzenlenir. Classpad kullanılarak ilk önce doğru sonuca ulaşan öğrenci yarışmayı kazanmış sayılır.

- Bir sayının 2 eksiği 127'dir
- Bir sayının 3 katı ilk problemin cevabına eşittir
- Bir sayı ile 10 un toplamı bir önceki sorunun cevabına eşittir
- -5 ten bir sayının çıkarılması bir önceki sorunun cevabına eşittir
- Bir sayı ile ikinin yarısının toplamı bir önceki sorunun cevabına eşittir
- Bir önceki sorunun cevabından bir sayının çıkarılması -12 ye eşittir
- Bir sayı ile - 9 un toplamı bir önceki sorunun cevabına eşittir
- Bir önceki sorunun cevabı ile 96 nın çarpımı bir sayıya eşittir,
- Bir önceki sorunun cevabı, 1 ile bir sayının çarpımına eşittir

#### Ölçme Değerlendirme:

- $2^n=8$  ise n kaçtır?
- $x.x.x.x.x.x=x$  ? çarpımını üslü niceik olarak ifade ediniz.
- $a=5$  ise  $a^{15}$  ifadesini hesaplayınız.
- $5^{26}=5673$  ifadesi doğru mudur?

## Ders Planı IV

**Sınıf Seviyesi:** 7. ve 8. Sınıf

**Öğrenme Alanı:** Cebir

**Alt Öğrenme Alanı:** Üslü nicelikler (7. sınıf)

Örüntüler ve İlişkiler (8. sınıf)

### Kazanımlar:

1. Tamsayıların kendileri ile tekrarlı çarpımını üslü nicelik olarak ifade eder.
2. 10'un pozitif ve negatif kuvvetlerini kullanır.
3. Çok büyük ve çok küçük pozitif sayıları bilimsel gösterimle ifade eder.
4. Özel sayı örüntülerinde sayılar arasındaki ilişkiyi açıklar.

### Öğretme Öğrenme Süreci

#### Isındırma:

Bu ders boyunca öğrenciler classpad ana menüde çalışırlar. Öğrencilerden bir bilinmeyen seçerek istedikleri sayıda yan yana yazmaları istenir. İşlem yap komutu verilince üslü ifade karşlarına çıkar. Bu kısa etkinlik öğrencilerin akıllarında sorular uyandırır ve üslü sayı ile tanışmalarında ilk adımdır.

#### Derse giriş:

Aşağıdaki sorular ana menüde ilgili fonksiyon kullanılarak çözülür.

- 20,39 sayısını çözümleyelim.
- $2 \cdot 10^2 + 0 \cdot 10^1 + 3 \cdot 10^{-1} + 9 \cdot 10^{-2}$
- $48^2, 2^{48}$
- Aylık 1,2 bin lira geliri olan bir banka çalışanı ile 1,2 milyon lira geliri olan Bill Gates'in gelirlerini üslü sayı şeklinde ifade ediniz.
- 1, 27, 729, 19683, ... şeklinde devam eden örüntünün sonraki 2 terimi kaçtır?
- Bu örüntünün 10. terimi kaçtır?



- $x^3 - y^3$  ifadesinin  $x=5$   $y=-3$  için alacağı değeri bulunuz.
- $x.x$
- $x.x.x$
- $x^0$
- $x^1$
- $x^2$
- $x^3$
- $x^0$
- $1^2 - 0^2$
- $2^2 - 1^2$
- $3^2 - 2^2$
- $4^2 - 3^2$  şeklindeki işlemler bir örüntü ile devam etmektedir. İlgili örüntüyü bulunuz.
- $17^2 - 16^2$
- $89^2 - 88^2$  cevapları örüntüye göre kaçtır?
- Bir fabrika ayda  $10^{11}$  kg küp şeker üretmektedir. Bu üretim için  $4.10^4$  m<sup>3</sup> elektrik ile  $2.10^2$  m<sup>3</sup> su tüketimi yapmaktadır.  $100^{11}$  kg küp şeker üretimi için kaç m<sup>3</sup> elektrik ve su tüketilir?

## Ders Planı V

**Sınıf Seviyesi:** 7. Sınıf

**Öğrenme Alanı:** Cebir

**Alt Öğrenme Alanı:** Cebirsel İfadeler

**Kazanımlar:**

1. İki cebirsel ifadeyi çarpar.
2. Cebirsel ifadeleri sadeleştirir.

**Öğretme Öğrenme Süreci**

**Derse giriş:**

Aşağıdaki cebirsel ifadeleri toplayınız.

- $(3x-5)+(5x+8)$
- $(x+7)+(-8x-17)$

Bu cebirsel ifadeler, classpad ile benzer terimler toplanmış olarak ifadenin en sade biçimine gelir. Öğrencilere, ifadenin sade hali ile ilk hali arasında nasıl bir benzerlik olduğu sorulur ve öğrencilerden hangi terimlerin toplanmış olduğunu tahmin etmeleri istenir.

Bir cebirsel ifadede, bir değişkenin aynı veya farklı katsayılara sahip olan terimlerine “benzer terim” dendiği belirtilir.

Benzer terimler toplanırken içinde bilinmeyen bulunan terimlerin önündeki katsayılar toplanır, bilinmeyenin katsayısı olarak yazılır. Classpad de yapılan işlemde, cebirsel ifadenin ilk hali ile sade hali karşılaştırılarak bu ifadenin doğruluğu görülür. Burada terim ve katsayı ifadeleri vurgulanır.

$$x^2+4x-5-3(x^2+5x)$$

$5+x-2x^2+2(x^2+4x)$  şeklindeki cebirsel ifadeleri en sade hale getiriniz / eş değerini bulunuz.

Sorunun çözümü için öğrencilerden bu ifadeyi classpad e girmeleri istenir. Eylem > Eşitlik/Eşitsizlik > Solve komutu verilir ve ifadeler en sade hallerini alırlar.

Öğrencilere aşağıdaki sorular yöneltilebilir:

- Sonuç ne oldu?
- Sizce bu sonuca ulaşmak için hangi işlemler yapıldı?
- Cebirsel ifadenin ilk ve son halini karşılaştırdığınızda nasıl bir ilişki görüyorsunuz?

Öğrencilerin varması beklenen ifadeler, benzer terimlerin katsayılarının toplanmış olması, cebirsel ifadenin en sade haline gelmesi, son ifadenin ilk ifadeye eş olduğudur.

Örnek Durum:

$$2(5k+3t)$$

$$10k+6t$$

Kurşun kalemler: k

Tükenmez kalemler: t

Yukarıdaki iki durumu model olarak gösteriniz. Modellerin cebirsel olarak nasıl ifade edilebileceği öğrencilere sorulur. İki model için oluşturulan cebirsel ifadelerin birbirine eşit olduğu modele bakılarak fark ettirilir.

Burada cebirsel ifadeler karşılaştırılırken çarpma işleminin toplama işlemi üzerine dağılma özelliği vurgulanır.

Cebirsel ifadelerin çarpımı için öğrenciler, aşağıdakileri ifadeleri classpad e girer ve hesaplatırlar.

- $(x-1).(x+2)$
- $(x-3).(2x-10)$
- $(2x+5).(x+4)$
- $(2x+5).(x+5)$
- $(2x+5).(x+3)$
- $(2x+5).(x+2)$
- $(2x+5).(x+1)$

- $(2x+5).x$
- $(a-1)^2+2a^2+6$
- $x.(x+5)$
- $2x.(x+5)$
- $3x.(x+5)$
- $x.(x+7)$
- $x.(x+8)$
- $x.(x+9)$

Yukarıdaki cebirsel ifadelerin açılımları, üslü ifade ve dağılma özelliği kullanılarak yapılır. Classpad’de yapılan işlemlerde, bu özelliklerin kullanıldığı, cebirsel ifadenin ilk hali ile son sadeleşmiş hali karşılaştırılarak fark ettirilir.

## Ders Planı VI

**Sınıf Seviyesi:** 7. ve 8. Sınıf

**Öğrenme Alanı:** Cebir

**Alt Öğrenme Alanı:** Denklemler (7. sınıf)

Cebirsel İfadeler (8. sınıf)

### Kazanımlar:

1. Birinci dereceden bir bilinmeyenli denklemi çözer.
2. Denklemi problem çözmede kullanır.
3. Özdeşlik ile denklem arasındaki farkı açıklar.
4. Özdeşlikleri modellerle açıklar.
5. Cebirsel ifadeleri çarpanlarına ayırır
6. Rasyonel cebirsel ifadeler ile işlem yapar ve ifadeleri sadeleştirir.

### Öğretme Öğrenme Süreci

#### Derse giriş:

Denklem ve cebirsel ifade için bir durum oluşturun sözel olarak ifade edin. Oluşturduğunuz durumu grup arkadaşınıza sözel olarak anlatın, arkadaşınız bu durumu classpad e yazsın.

- 259 tane şeker 4 kutuya eşit sayıda doldurulmuş, 23 şeker ise dışarıda kalmıştır. Bu duruma uygun olan modeli çizin ve bu modelden yola çıkarak denklemi kurunuz.

Denklem çözümlerinde eşitliğin korunumuna dikkat çekilir. Eşitliğin bozulmaması için her iki tarafa da aynı işlemin yapılması gerektiği vurgulanır.

Denklemde +23 şekerini yok etmek için tersi olan -23 ile toplama yapıldığı, 4 katı yok etmek için tersi olan  $\frac{1}{4}$  ü ile çarpma yapıldığı belirtilir.

- Çiftçi Ali, fasulye tarlasının çevresini çitlerle çevirmek istemektedir. Ne kadar çit kullanacağını belirlemek için tarlanın çevresini adımları ile ölçer.

Tarlanın enini 32 adım, boyunu ise 42 adım olarak ölçmüştür. Tarlanın çevresini cebirsel olarak ifade ediniz. Ali'nin adımı 50 cm ise tarlasını çevirmek için kaç cm uzunluğunda çit kullanmalıdır?

- Bir kantar 42 kasa elma ile 32 kg şeftali tartıldığında A kg göstermektedir. 23 kasa elma ile 120 kg şeftaliyi tarttığında da A kg gösterdiğine göre, 1 kasa elma kaç kg dır?

Rasyonel katsayılı işlemler için örnek sorular:

- Öykü, doğum günü partisi için aldığı X tane 1.5 litrelik meyve suyu partideki arkadaşlarına yetmeyince, 2 tane daha 2,5 litrelik meyve suyu ilave olarak almıştır. Toplam 12,5 litre meyve suyu alındığına göre, Öykü kaç tane 1,5 litrelik meyve suyu almıştır?

Aşağıdaki eşitliklerde bilinmeyeni bulunuz.

- $6x/5 - 5 = x + 20$
- $a - 7/8 = 42$
- $4x^2 - 5x + 17 = 2(7 + 2x^2)$
- $1/6 x + 12 = 4 + 2/3 x$

## Ders Planı VII

**Sınıf Seviyesi:** 7. ve 8. Sınıf

**Öğrenme Alanı:** Cebir

**Alt Öğrenme Alanı:** Denklemler (7. ve 8. sınıf)

**Kazanımlar:**

2. İki değişken arasındaki doğrusal ilişkiyi tablo ve grafik kullanarak inceler, bir değişkenin diğerine bağlı olarak nasıl değiştiğini açıklar.
3. İki boyutlu kartezyen koordinat sistemini açıklar ve kullanır.
4. Doğrusal denklemlerin grafiğini çizer.
5. Doğrunun eğimini modelleri ile açıklar.
6. Doğrunun eğimi ile denklemin arasındaki ilişkiyi belirler.
7. Bir bilinmeyenli rasyonel denklemleri çözer.
8. Doğrusal denklem sistemlerini cebirsel yöntemlerle çözer.
9. Doğrusal denklem sistemlerini grafik kullanarak çözer.

### Öğretme Öğrenme Süreci

**Isındırma:**

- Coğrafya’da enlem ve boylam ne için kullanılır?
- Bir futbol sahası şekli öğrencilere gösterilir. Futbolcuların, futbol oynama yeteneklerine göre sahada yerlerinin belirlenmesinin kriterleri, futbolcuların nerelerde yer aldığı şeklinde sorular sorulur. Forvet, savunma ve orta saha gibi bölgeler örnek futbol sahası üzerinde gösterilir.
- Bir gprs / yol belirleme cihazı örneği gösterilir. Arabanın bir semtte nerede olduğunu ekranda nasıl belirtilir? Gprs cihazını kendimiz oluştursak, Kızılay’dan başkente gelişi nasıl anlatırız? şeklinde sorular yöneltilir. Başlangıç noktasından (Kızılay) yola çıkıldığında yön belirterek bitişe

(Başkent) varmaları beklenir. Yer tarifi için ne tür bilgilere ihtiyaç duyulacağı, bunun kağıt üzerine nasıl çizilebileceği sorulur.

- Haritaların nasıl oluşturulduğu sorulur. Bir yer belirleme sistemine ihtiyaç hissettirilir.

### **Derse Giriş:**

Öğrenciler Classpad'teki geometri menüsünü kullanır. Her öğrenci okul, ev ve market uzaklığı belirtme amaçlı bir üçgen çizer. Üçgenin köşelerini “O” (okul), “E” (ev) ve “M” (market) şeklinde adlandırır. Bu adımdan sonra, arka planda noktalı kağıt görünümü oluşturma fonksiyonunu kullanmaları istenir. Ev, okul ve market arasındaki yollarla ilişkilendirdikleri bir hikaye kurmaları istenir. Başlangıç noktası, yön, uzaklık, yöndeki değişim ve nokta gibi ifadeler kullanmaları beklenir. Bu ifadelere gerek duyulduğu vurgulanır.

Öğrenciler ikili gruplar halinde çalışırlar. Birbirlerine çizdikleri üçgeni anlatırlar. Amaç diğerinin bu anlatımdan yola çıkarak kendi noktalı ekranına arkadaşının ekranındaki üçgeni aynı özelliklerle çizebilmesidir. Bu çizim yapılırken, geometri menüsündeki uzaklık ölçme araç çubuğu kullanılarak 3 yer arası uzaklıklar belirtilir. Öğrencinin, ekranda hangi yönde kaçınıcı noktaların kullanıldığını belirtmeye ihtiyaç duyması beklenmektedir.

Çalışma tamamlandığında, yeri yön ve uzaklıkların belirlemelerinin çok zaman aldığı vurgulanır. Buna rağmen farklı çıkan şekiller olabileceği söylenir. Bu zorluklardan dolayı koordinat sisteminin kullanıldığı söylenir ve arka planda kartezyen sistem oluşturma fonksiyonunu kullanmaları istenir.

Dersin devam eden kısmında classpad in ana menüsü kullanılacaktır. Öğrenciler ikili gruplar halinde aşağıdaki problem üzerinde çalışırlar. Classpad e-aktivite menüsünü kullanırlar.



- 1kg reçel yapabilmek için 3kg çilek kullanılır.

Reçel (kg)	Çilek (kg)	İlişki
1	3	$r=3ç$
2	6	
3	9	
n		

- Yukarıdaki tabloyu doldurun.
- Reçel ile çilek miktarları arasında nasıl bir ilişki var?
- Çizgi grafiği çiziniz, tablodaki değerleri kullanarak ve grafiğin eksenlerini tablodaki ilgili başlığa göre isimlendiriniz.

Aşağıdaki sorular sınıfa yönlendirilerek, öğrencilere doğrusal grafik kavramı fark ettirilir.

- Şekil hangi geometrik şekle benziyor?
- Başlangıç ve bitiş noktası nerede?

İkili gruplar halinde çalışma yapılarak aşağıdaki sorular üzerinde tartışılır.

- 30 kg çilek ile kaç kg reçel yapılabilir?
- 10 kg reçel yapmak için kaç kg çilek gerekir?

Grup içindeki kişilerin birbirlerini benzer sorular yöneltmeleri istenir. Sınıf içi tartışmalarla, sonuca ulaşmak için grafikten, denklemden veya değer tablosundan yararlanılabileceği belirtilir.

Doğrusal ilişki, iki değişkenden oluşan  $ax+by+c=0$  şeklindeki cebirsel ifade ile gösterilebilir. Doğrusal denklemlerin bir sabit sayı ile katsayılı iki değişkenden oluşan terimler içerdiği ve  $ax+by+c=0$  biçiminde olduğu, a ile b katsayılarının aynı anda “0” olamayacağı vurgulanır.

- Bir mum her 30 dakikada 2,5 cm erimektedir.

Buna göre;

- Mumun uzunluğu ile geçen süre arasındaki ilişkiyi bir tabloda gösteriniz.

- Mumun uzunluđu 25 cm ise kaç dakika sonra biter? (öğrencilerin denklem oluşturmaları beklenir.)
- Bu ilişki doğrusal mıdır? Açıklayınız. (Öğrencilerden denklemin grafiğini çizmeleri beklenir.)

Grafik hesap makinesi kullanımında denklem, grafik ve değerklik tabloları çoklu temsilinden yararlanılarak etkili bir biçimde kullanılır.

Aşağıdaki ifadeleri cebirsel ifade şeklinde Classpad e yazınız.

- Bir sayının 7 ye bölümünün karesi
- Bir sayı ile 6 nın 12 ye bölümünün toplamı
- Bir sayının 3 katının 2 fazlası
- Bir sayının 5 eksiğinin 4 katı
- Bir sayının karesinin 8 katı
- Güneş, Türkiye'nin en doğu ucunda en batı ucundan 77 dakika erken doğar. (doğu: d, batı: b)

Aşağıdaki ifadeleri denklem şeklinde yazınız.

- Bir sayının 9 katının 5 eksiği 42 dir
- Kendisinin 3 fazlası 7 olan sayı d dir
- Duygu markete cebinde 50 lira ile gidiyor. 3 paket sakız ve gofret alıyor. Gofretler için 23 lira ödediğine göre, bir paket sakızın fiyatı ne kadardır?
- Arif, arkadaşlarıyla bowling oynamaya gider. Ayakkabı kiralama 3 lira, her oyun için ödenecek ücret ise 6 liradır. Toplam 21 lira ödeyen Arif, kaç tur oyun oynamıştır?
- Otel sahibi olan Berke bey, otel binası dışında kalan alanı havuz yapmaya ayırmıştır. Bu alanın çevresi 86 metredir. Havuzun eni 16 metre olduğuna göre boyu kaç metredir? Havuzun eni 11 metre olsaydı boyu tam sayı olarak kaç metre olabilirdi?
- Olimpiyatlara katılacak olan Türk atlet Özlem, her gün koşuya çıkmaktadır. İlk gün 10 km, 2. gün sonunda 14 km, 3 . gün sonunda ise 18 km koşmuştur.

Bu periyotta koşu yapmaya devam ederse, 21 gün sonunda kaç km koşmuş olur?

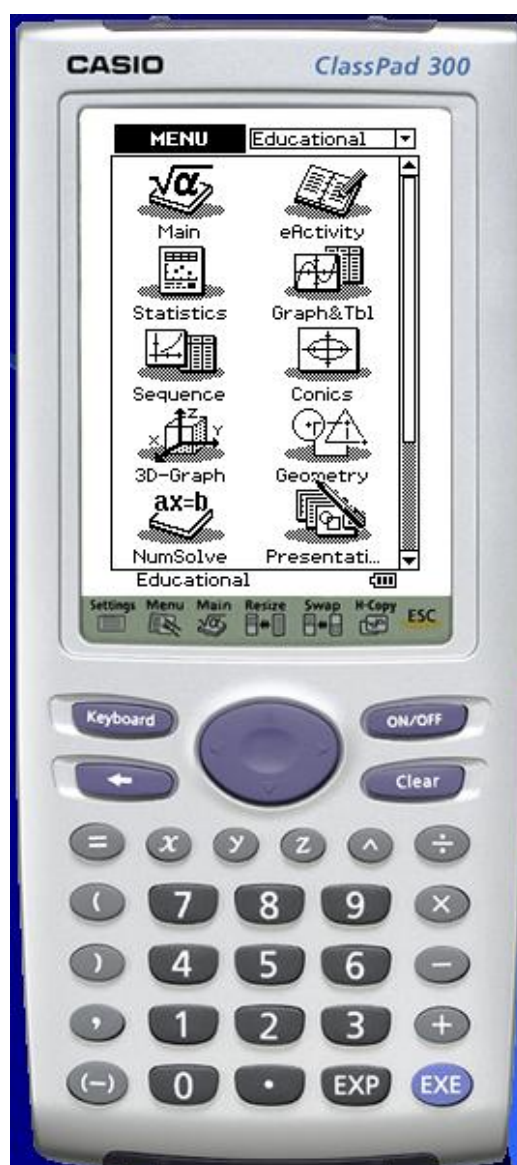
- Fiyatları aynı olan gömleklerden 5 adet alan Mehmet bey, gömlekler için 520 lira ödeyip t lira para üzeri almıştır. Bir gömlek için ödenen parayı gösteren cebirsel ifadeyi yazınız. Para üzeri 100 lira ise 1 gömlek için ödenen fiyat nedir?
- Amerika'nın 52 eyaleti 4 zaman dilimini kullanmaktadır. Bu, dünyanın zaman dilimlerinin  $\frac{1}{6}$  sına karşılık gelmektedir. (t: dünyadaki zaman dilimleri)
- Bir aslanın ortalama yaşam süresi, ortalama yaşam süresi 7 yıl olan zebranın 2 katının bir yıl eksikidir. ( t: aslanın ortalama yaşam süresi)
- Pasifik ve Atlantik okyanusları, dünyanın en büyük iki okyanusudur. Atlantik ortalama olarak 86 560 000 km karelik bir alana sahiptir. Pasifik ise Atlantik in 1.9 kat büyüklüğünde bir alandır. (y: Pasifik okyanusun alanı)
- Gülümserken 17 kasımızı kullanıyoruz, bu da kaşlarımızı çatarken kullandığımız kaslarımızın iki katının 9 fazlasına eşit olmaktadır. (x: kaşlarımızı çatarken kullandığımız kaslarımızın sayısı)
- Büyük bir Anaokulu sahibi olan Tuğçe hanımın 18 tane 5 yaşında ve 32 tane 6 yaşında öğrencisi vardır. Tuğçe hanımın 5 yaşında olan bir kaç öğrencisi ailesi ile birlikte yurtdışına gitti. Giden öğrencilerin iki katı kadar 5 yaşında öğrenci geldi. Son durumda anaokulundaki 5 ve 6 yaşındaki öğrenci sayısı eşit olmuştur. Problemin sorusunu yazınız, denklemini kurunuz ve çözünüz.
- $6y + 3 = 33$  denklemine uygun bir problem kurunuz ve çözünüz.
- Bankacı Burak Bey'in 159.000 lirası vardır. Her ay 2000 lira prim aldığına göre x ay sonra kaç lirası olur? 207.000 lira olması için kaç ay prim alması gerekir?

### Ölçme Değerlendirme:

Öğrencilere yukarıdaki soruların grafiklerinin çizimini yapmaları ve benzer örnekler yazarak e-aktivite hazırlama görevi verilir.

## **APPENDIX B**

### **CASIO CLASSPAD 330 TUTORIAL**



# Main Toolbar

## ▼ menu

Change settings,  
bring up the keyboard,  
or close the application

## Edit menu

Undo/redo,  
Cut/copy and paste,  
Delete, Select All,  
and Clear all

## Action and Interactive menus

Two different ways of entering  
ClassPad's commands  
(more information in next section)

## Approximation button

Converts the selected  
output from a fraction  
to a decimal or  
vice versa



## Access Application

Allows you to create  
a window so you can  
view another application  
at the same time.

## Output as is

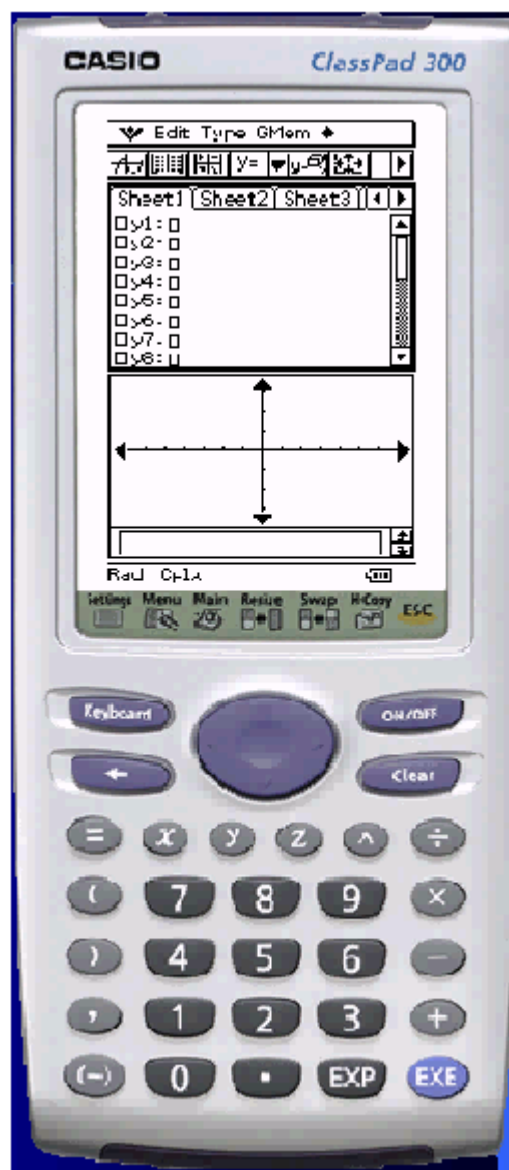
Output the current  
expression as is.  
No calculation performed

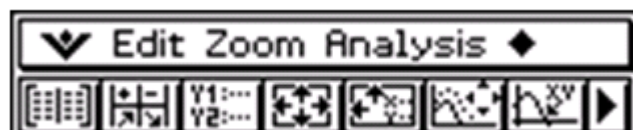
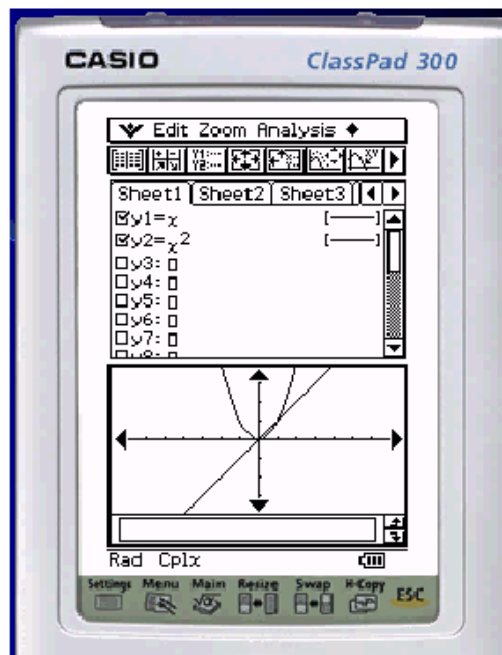
## Variable Manager

See which variables  
are defined, and what  
their values are



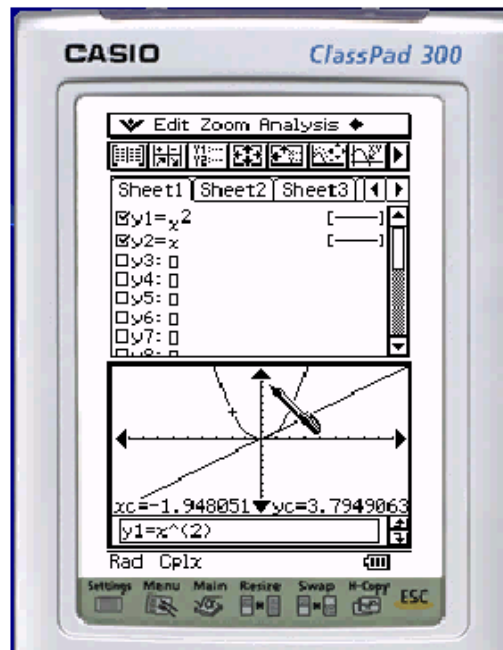
1. Introduction to graphing and analysis with the graph and table application





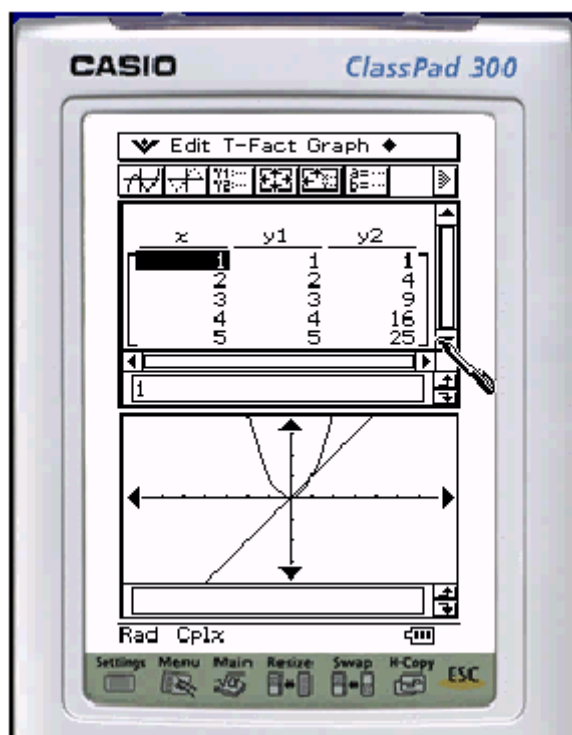
The button at the end corner is for tracing the graph which lets you follow the graph with a pointer and gives you the coordinates of points on the graph. To trace a graph, press the trace button. Then, use the arrow pad, or arrows in the window. Left/right let you trace the graph, up/down switches between graphs.






### Calculating maximums, minimums, intercepts

Creating a Table of a Function. Allows you to create a table of values for a function or graph. Lets you quickly view results without having to trace. In the graph window, or graph editor, tap the table button. A table will come up with a list of x and y values for the current functions you have in your list (or on your graph.)

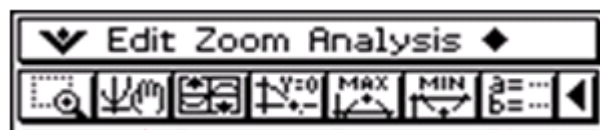


Will create a table of values for  $y = x$  and  $y = x^2$  for  $x = 1, 2, 3, 4, 5$ . To close the table window, go to the  menu in the upper left and tap close.

The fifth button is for the functions related with modifying a table. The default table is  $x = 1, 2, 3, 4$  and  $5$ . You can change this by selecting the table input button. A screen will come up which asks for start, end, and step (increment) values. For example: To create a table with  $x = 1, 1.5, 2$  enter Start = 1, End = 2, Step = .5

### Table Input

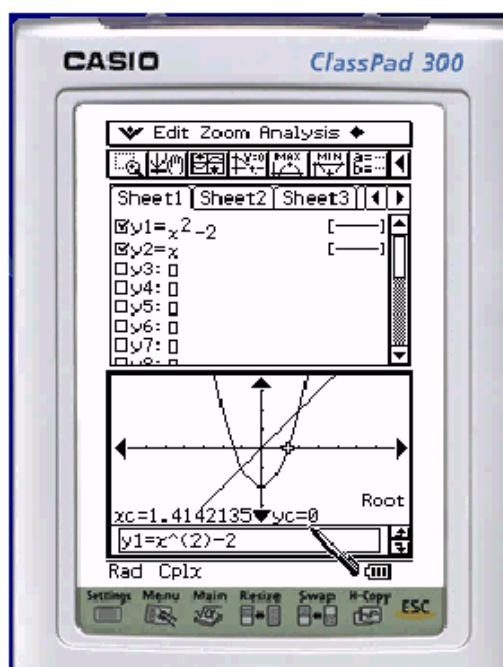
Start :   
 End :   
 Step :



First button or use the keyboard select zoom menu to zoom.

Second button is for panning.

ClassPad will easily calculate a function's maximum, minimum, or roots (x-intercepts). Each calculation has a button on the toolbar, 4<sup>th</sup>, 5<sup>th</sup> and 6<sup>th</sup> buttons, respectively.



### Analysis Menu

This section has been a brief introduction to graph and function analysis. More advanced operations can be accessed through the analysis menu.

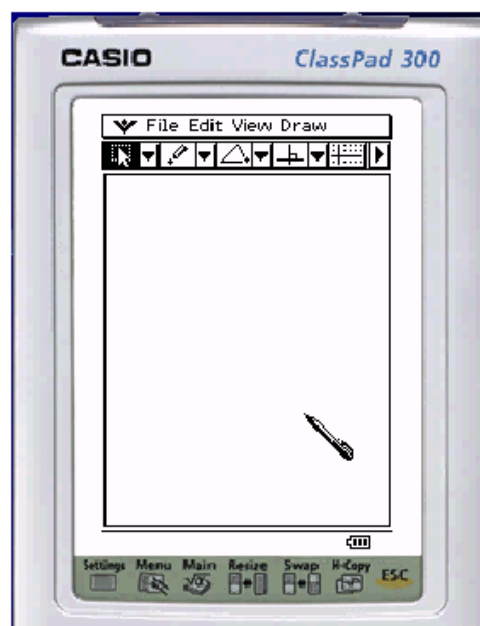
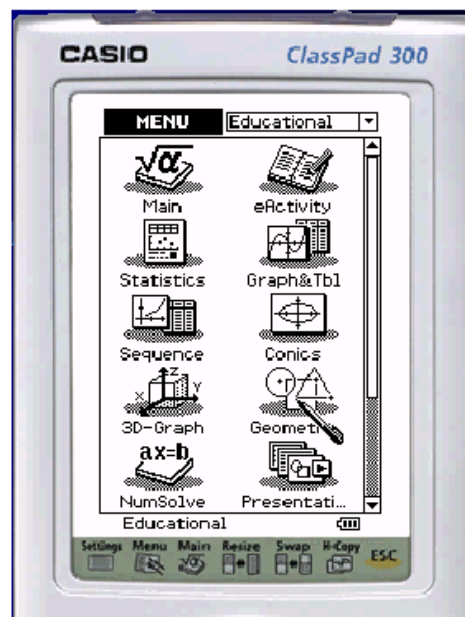
ClassPad has other applications that allow you to create different kinds of graphs; conics, 3D graphs, and statistics.

This section is an introduction to the ClassPad's geometry system

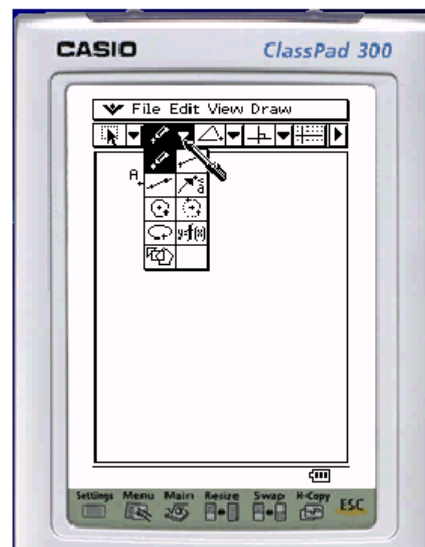
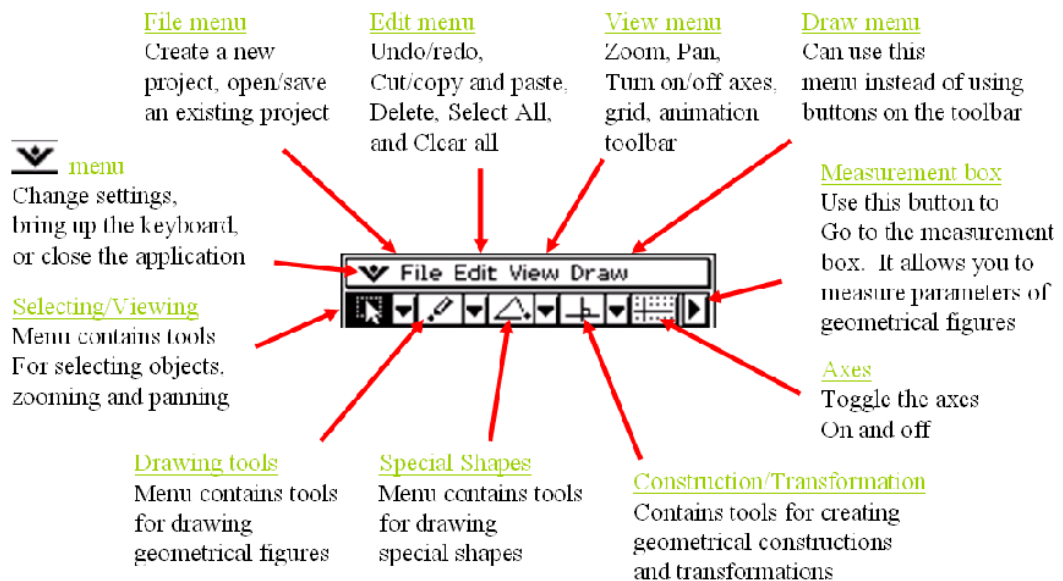
### Geometry Application

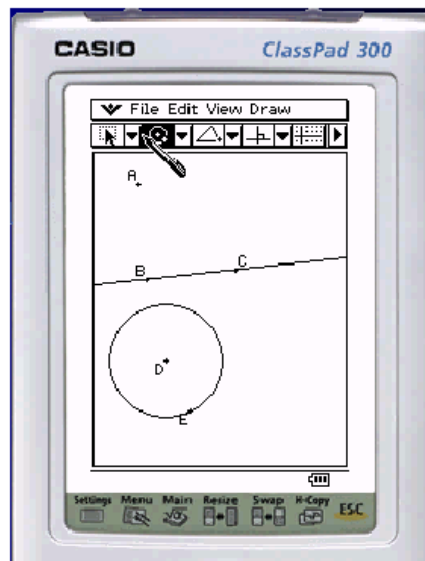
Create and analyze geometrical figures from the geometry application

Access it by selecting *Geometry* from the Main menu



# The Geometry Toolbar





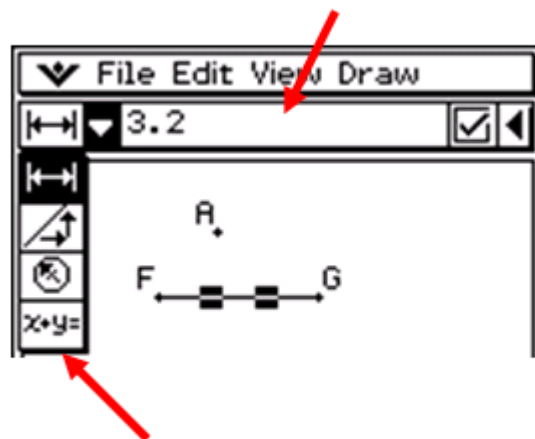
You can drawing other figures, such as points, lines, circles, arcs, ellipses, and polygons. You can move and modify your figures by selecting and dragging.

### Measurements

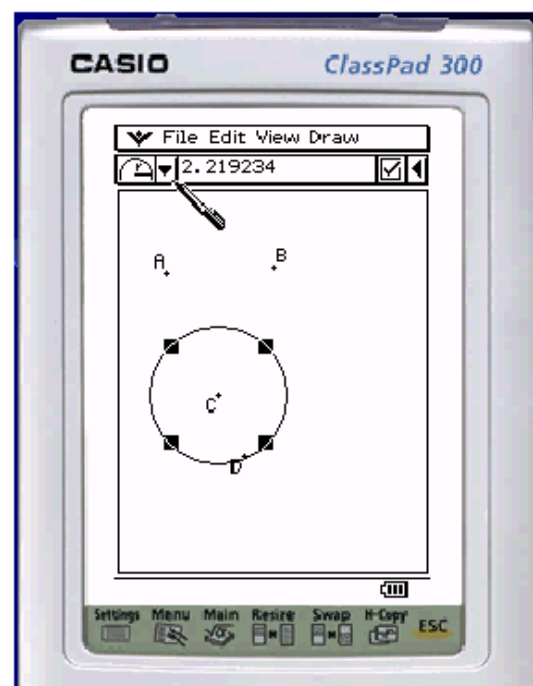
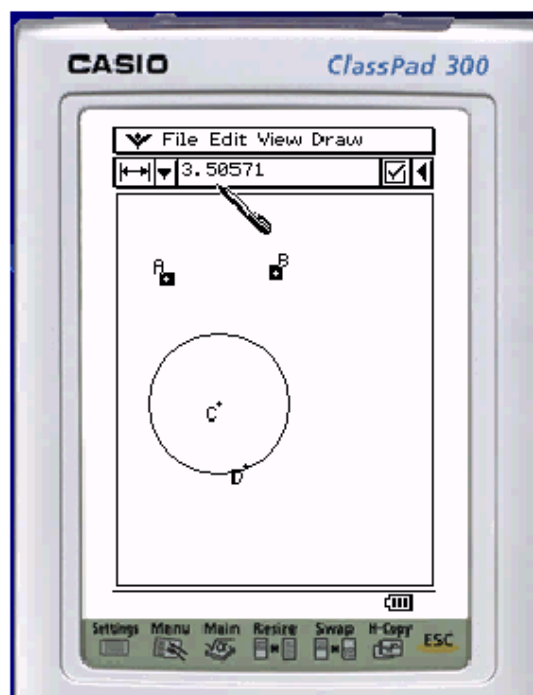
Instantly make a measurement of your choosing on a figure

Tap the arrow at the far right of the toolbar to go to the measurement box. Select the figure or figures you would like to measure.

## Measurement Box



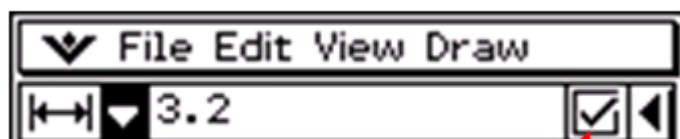
## Measurement Menu



The two scenes captured from the geometry menu present the measure of the distance between two points, and the area of a circle, respectively. The measurement options change depending on what is selected.

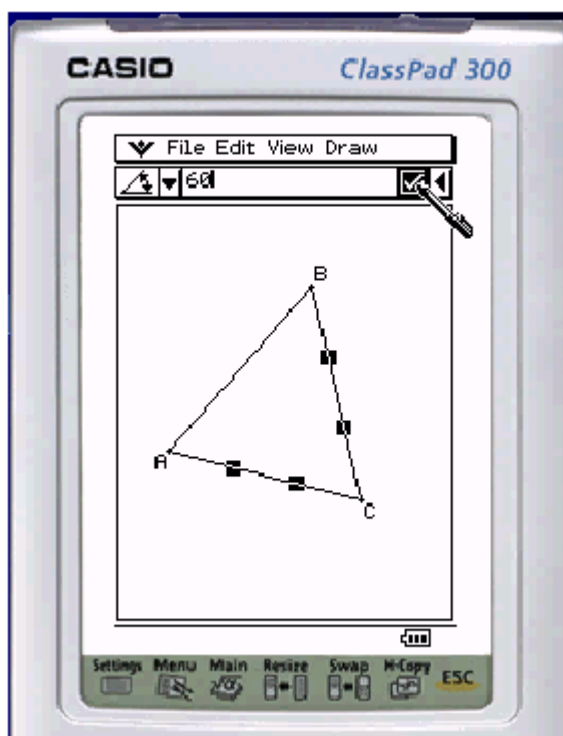
### Constraint Geometry

You can “lock” some parameters so they will not change even if you move the object. Select the measurement you want to lock from the measurement menu.



## Lock measurement

A scene from constructing an equilateral triangle using only constraints is shown on the Classpad window below.





First, you lock the length of two sides to be 1 unit, and an angle to be 60 degrees as shown in the figure. Then, you check that the length of the third side is the same as the other two.

### Construction / Transformation

You can create geometrical constructions, and perform transformations from the construction/transformation menu. Firstly, select the figure(s) you want to operate on. Then, select the operation from the menu. Moreover, transformations require some additional input. You can follow directions at the bottom of the screen.

### Construction / Transformation Menu Explanation

#### Perpendicular Bisector

Bisect a line segment or two points

#### Midpoint

Create a midpoint of a segment or two points

#### Angle Bisector

Bisect an angle

#### Tangent

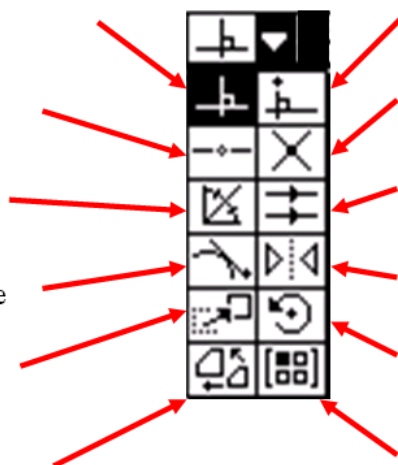
Create a tangent to a curve

#### Translation

Translate selected objects

#### Dilation

Dilate selected objects with respect to a dilation center



#### Perpendicular Line

Create a perpendicular line through a selected point

#### Intersection

Construct an intersection of two objects

#### Parallel Line

Construct a parallel line through a selected point

#### Reflection

Reflect objects in a line or segment

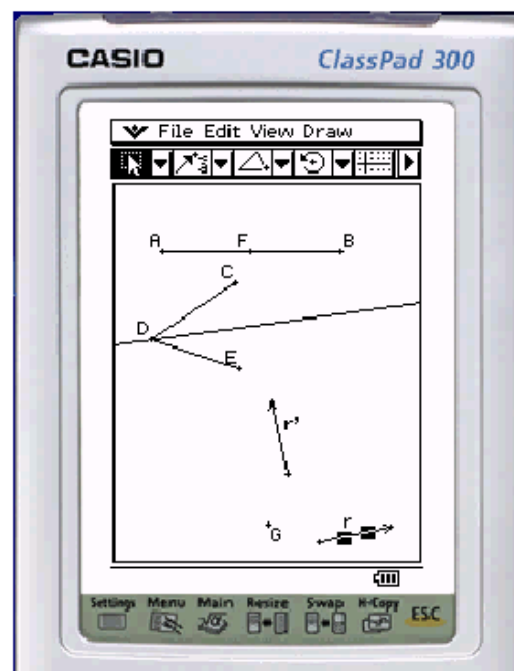
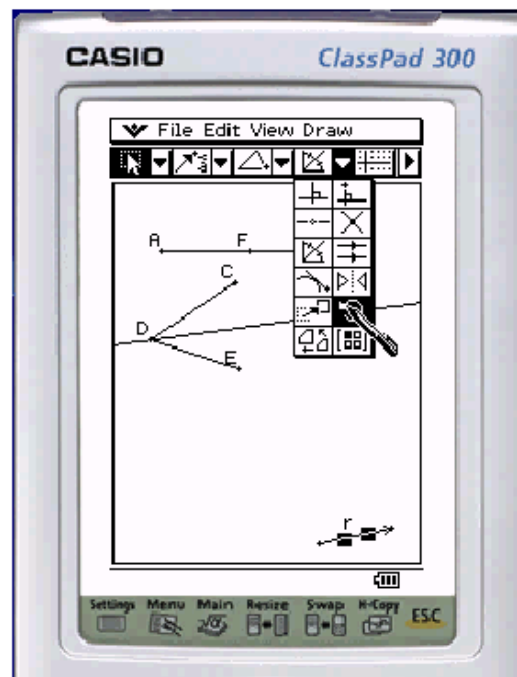
#### Rotation

Rotate objects about a point

#### General Transformation

Transform objects with a matrix

As an example, you can construct a midpoint of a segment, bisect an angle and rotate a vector 90 degrees, which is presented in the figure below.



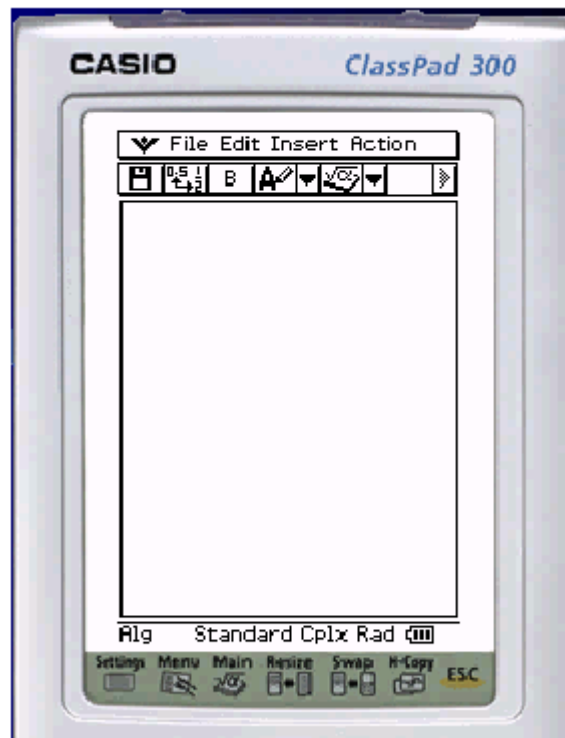
### E-Activity menu

ClassPad's eActivity application is a versatile application that allows the user to apply the ClassPad skills.



### **The eActivity Application**

Integrates text, calculations, geometry and all other applications. Allows save/load of files. Access it by choosing the eActivity icon from the main menu.



## The eActivity toolbar

### File menu

Create a new project, open/save an existing project

### Edit menu

Undo/redo, Cut/copy and paste, Delete, Select All, and Clear all

### Insert Menu

Insert rows, geometry links, application strips

### Action menu

Enter ClassPad's calculation commands

### ▼ menu

Change settings, toggle the keyboard, close the application

### Application Strip Menu

Insert modules to access other applications

### Open/Save

Save the project, open another project

### Approximation

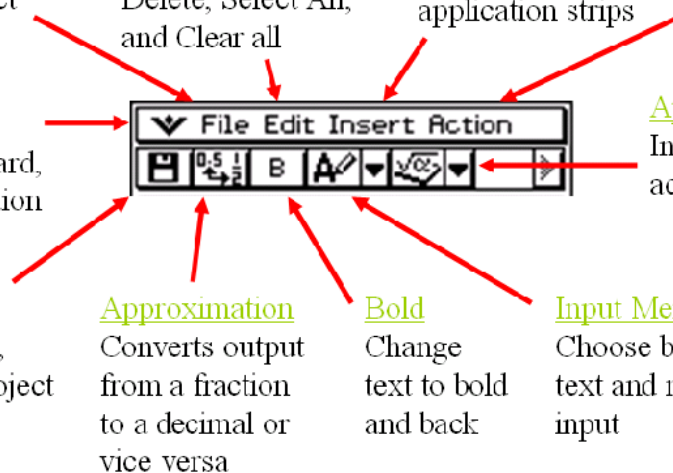
Converts output from a fraction to a decimal or vice versa

### Bold

Change text to bold and back

### Input Menu

Choose between text and math input



## Saving and Opening

You can save your current eActivity, or open another one. Either use the file menu, or the open/save button on the toolbar.

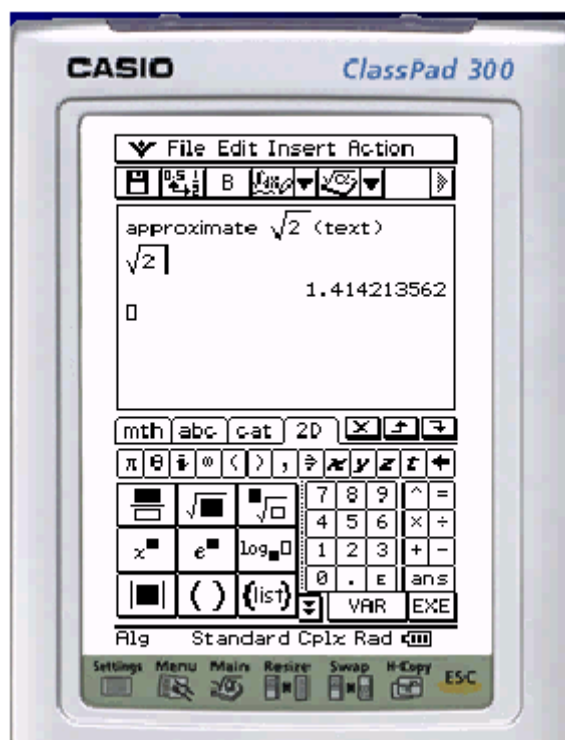


## Text and Math Input

Inside the eActivity application, there are two types of input: Text (EXE will not evaluate), and Math (EXE will evaluate). Choose the format for the current line from the input menu. You can change a line's input format at any time.

**Calculation**  
**Text (default)**

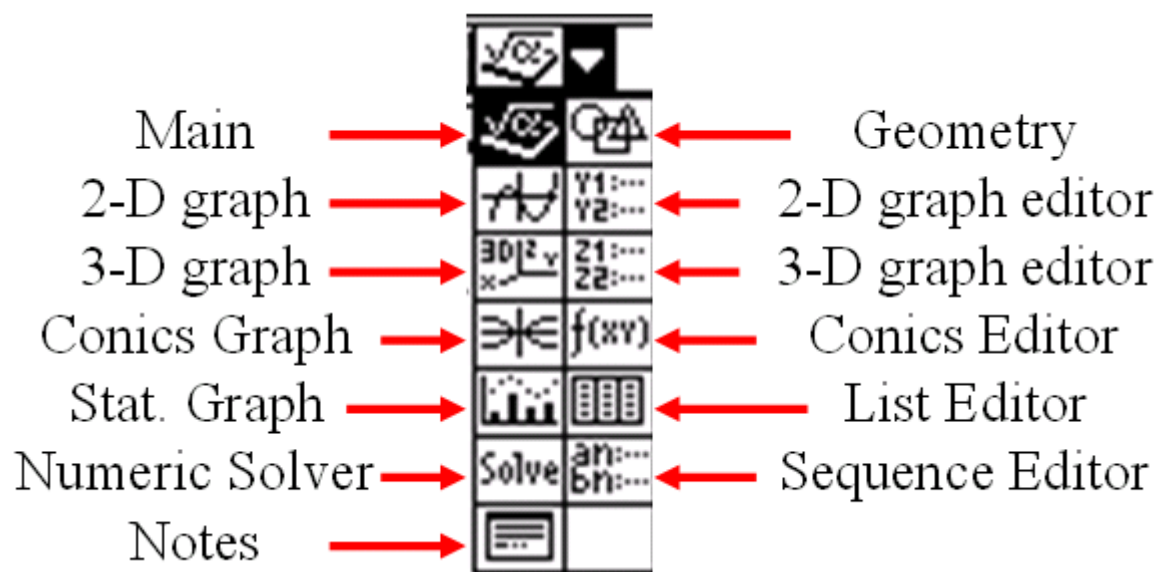




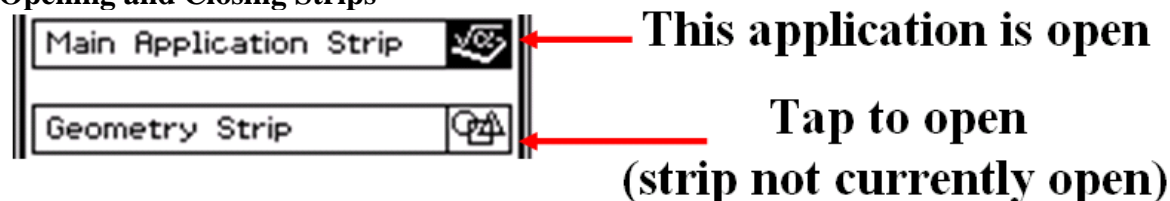
Text lines are good for comments and explanations. Math lines are good for calculations and demonstrations.

### Application Strips

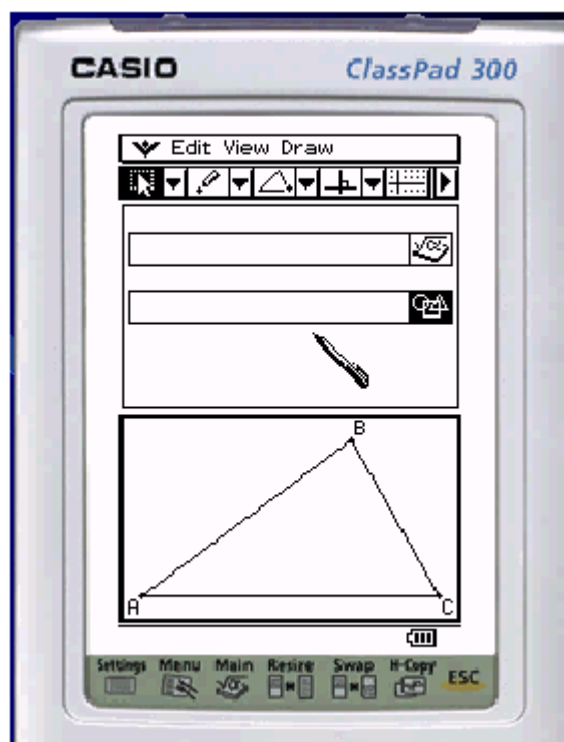
You can run most other applications from within eActivity by inserting application strips. Use the insert menu, or the application strip menu on the toolbar:



#### Opening and Closing Strips



To open an application, tap the icon at the far right of the strip; a window of that application will open. To close the application, move the cursor to the open window and select close from the menu in the upper right.



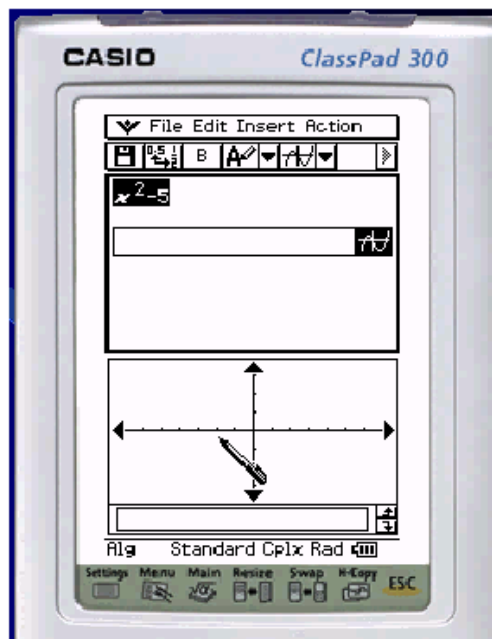
Above is an example where two application strips are inserted. You can open or close each one by clicking on the icons at the right end of the application lines, such as, in the figure, the top line has the icon of main menu and the second line has the icon of geometry menu. Only one strip can be open at once. In the figure, geometry strip is open.

### **Working with application strips**

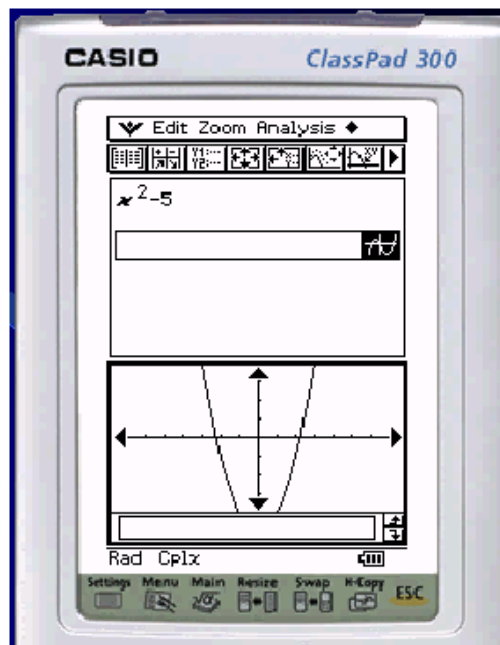
You can cut/copy and paste data between eActivity and the other applications. You can also drag and drop objects from eActivity to the application window, or the other way around. Useful for getting a visual representation of a math expression, or finding the precise math equation for a graphical object.

This example will write the equation of a function, then drag and drop it into a graph application.





While dragging the equation to the coordinate axis window.

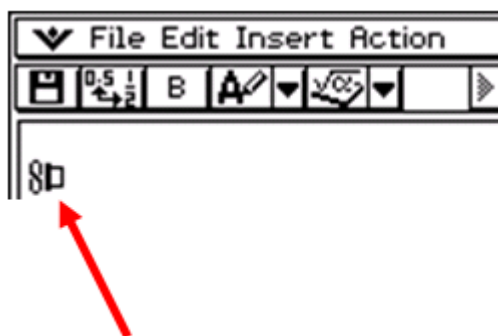


After dragging the equation to the coordinate axis window.

You can also work the other way around, by dragging graphs into eActivity to view the equations.

## Geometry links

eActivity is very useful for analyzing geometry. Geometry links will automatically update when a change is made to the geometry window. To insert, tap *Geometry Link* from the insert menu. Drag and drop an object from a geometry window onto the link



## Empty Geometry Link

As an example, when creating a geometry link to a line; if you change the contents of the link, the line will update itself. If you change the line, the link will update itself.

You can find further activities on [Classpad.org](http://Classpad.org); such as two ways to calculate roots of a parabola, two ways to find the inverse of a line, two ways to find the intersection of a line and a semi-circle, etc.

## APPENDIX C

### QUESTIONNAIRE

Ders: Matematik  
Sınıf: 6, 7, 8  
Öğrenme Alanı: Cebir  
Araç: Classpad

<b>Hafta</b>	<b>Sınıf Düzeyi</b>	<b>Menüler</b>	<b>Düşünceleriniz</b>
<b>1. Hafta</b>	Eğitim	Ana Menü Geometri Grafik ve Tablolar	
<b>2. Hafta</b>	6. sınıf	Ana Menü Grafik ve Tablolar Geometri	
<b>3. Hafta</b>	6. sınıf 7. sınıf	Ana Menü Grafik ve Tablolar	
<b>4. Hafta</b>	7. sınıf	E-aktivite Geometri	
<b>5. Hafta</b>	7. sınıf 8. sınıf	E-aktivite Geometri Spreadsheet	

1. Sizce Classpad programının kullanılması cebir konusunu öğrenmenizde size ne gibi katkılar sağladı?
2. Cebir konusunu öğrenmenizde Classpad programını kullanırken ne gibi zorluklarla karşılaştınız?
3. Sizce Classpad programının cebir konusunu öğrenirken kullanılmasının avantajları nelerdir?
4. Sizce Classpad programının cebir konusunu öğrenirken kullanılmasının dezavantajları nelerdir?
5. Classpad grafik hesap makinesi ilgili başka neler söylemek istersiniz?

## APPENDIX D

### INTERVIEW QUESTIONS

- 1) Classpad'i kullanım şekli, işlem kolaylığı ve çoklu gösterim açısından değerlendirecek olursanız olumlu ve olumsuz yanları sizce nelerdir?
  - Cebir konusunu öğrenirken Classpad kullanımının size kolaylık sağladığı kısımlar oldu mu?
  - Hangi konular?
  - Cebir çalışmasında Classpad'in hangi menülerinden yararlandınız? En çok hangileri işinize yaradı?
  - Classpad kalem kağıdın sağladıklarından farklı olarak ne gibi avantajlar sağladı? Cebir konusunun öğretiminde, sınıfta yapılan çalışmalardan örnek verebilir misiniz?
- 2) Sizce Classpad'in Cebir öğrenimi konusunda kullanılması uygun mudur?
  - Konunun hangi kısmında uygun? Hangi kısmında uygun değil?
  - Cebir konusunu öğrenirken Classpad kullanımının sınırlılıkları var mıydı?
  - Hangi konuda? Hangi örnek üzerinde çalışırken?
  - Nasıl aşılabılır?
  - Classpad'in rolü ne olmalıdır?
  - Classpad kullanımı ile cebir öğrenimi sürec sonunda, cebirle ilgili düşüncelerinizde bir değişiklik oldu mu?
  - Classpad kullanımı cebir öğreniminizi ne yönde etkiledi? Örnek verebilir misiniz?
  - Nasıl öğrendiğinizi etkiledi mi? Ne yönde? Örnek verebilir misiniz?
  - Etkili kullanımı için önerileriniz nelerdir?
  - Classpad kullanmak Cebir e karşı düşüncelerinizi nasıl etkiledi?
  - Ne öğrendiğinizi, nasıl öğrendiğinizi nasıl etkiledi?
  - Classpad, 6. 7. ve 8. sınıf cebir öğrenme alanı konularında kullanıldı. Bu sınıf düzeylerinde ve ilgili konuda classpad kullanılmasıyla ilgili ne düşünüyorsunuz?
  - Sizce kaçınıcı sınıfta ve hangi konularda öğrenci bunu kullanmaya başlamalı?
  - Türk eğitim sistemine nasıl entegre edilebilir?
- 3) Classpad kullanımı motivasyonunuzu ne yönde etkiledi?

- 4) Sizce Classpad hangi matematik konularında kullanılabilir?
- Konuların hangi kısımlarında, ders işleyişinin hangi basamaklarında (ders planı basamaklarında; giriş, etkinlik, örnekler, ölçme değerlendirme) daha etkili olur?
  - Siz öğretmen olarak grafik hesap makinesi kullanmayı tercih eder misiniz? Neden?
  - Bir öğretmen adayı olarak Classpad'ın Cebir konusunda sınıf içinde kullanımı ve kullanım şekliyle ilgili ne düşünüyorsunuz?
- 5) Daha gelişmiş bir grafik hesap makinesi üretilmesi için önerileriniz var mı?
- Classpad'de olan ve olumlu bulduğunuz özellikler nelerdir?
  - Classpad'de olan ve olumsuz bulduğunuz özellikler nelerdir?
  - Classpad'de olmayan önereceğiniz özellikler nelerdir?