A SURVEY OF HIGH SCHOOL MATHEMATICAL KNOWLEDGE AND SKILLS NEEDED FOR ENGINEERING EDUCATION

A MASTER'S THESIS

BY

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THE PROGRAM OF CURRICULUM AND INSTRUCTION
BILKENT UNIVERSITY
ANKARA

MAY 2013

To my dearest mother and father

A SURVEY OF HIGH SCHOOL MATHEMATICAL KNOWLEDGE AND SKILLS NEEDED FOR ENGINEERING EDUCATION

The Graduate School of Education

of

Bilkent University

by

Mehmet Başaran

In Partial Fulfilment of the Requirements for the Degree of

Master of Arts

in

The Program of Curriculum and Instruction
Bilkent University
Ankara

May 2013

BILKENT UNIVERSITY
GRADUATE SCHOOL OF EDUCATION
A SURVEY OF HIGH SCHOOL MATHEMATICAL KNOWLEDGE AND SKILLS NEEDED FOR ENGINEERING EDUCATION
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May 2013

I certify that I have read this thesis and have found that it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Arts in Curriculum and Instruction.

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ABSTRACT

A SURVEY OF HIGH SCHOOL MATHEMATICAL KNOWLEDGE AND SKILLS NEEDED FOR ENGINEERING EDUCATION

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May 2013

The focus of the study is to explore if there is a difference among the engineering departments based on the topics and skills that students are expected to gain in high school, by investigating importance levels of the topics and skills. For the purpose of identifying importance levels mathematical topics and skills, university staffs with different academic ranks from different universities were asked with a questionnaire including Likert scale items to express their opinions about topics and skills in high school mathematics curricula of both National Curriculum and International Baccalaureate Diploma Program (IBDP). The main conclusion drawn from present study were that packaged curricula for specific engineering departments in university can be designed for high schools and the core topics required for engineering departments should be included in earlier grade levels. Besides, some topics from IBDP should be considered to be added to Ministry of National Education (MoNE) curriculum.

Key words: Mathematics curriculum, mathematics topics, engineering education, mathematical skills, differentiated curriculum.

ÖZET

MÜHENDİSLİK EĞİTİMİ İÇİN GEREKLİ OLAN LİSE MATEMATİK BİLGİSİ VE BECERİLERİ ÜZERİNE BİR ANKET ÇALIŞMASI

Mehmet Başaran

Yüksek Lisans, Eğitim Programları ve Öğretim

Tez Yöneticisi: Yard. Doç.Dr. İlker Kalender

Mayıs 2013

Bu çalışmanın odak noktası öğrencilerin liseden kazanması beklenen konular ve becerilerin önem derecelerini inceleyerek konular ve beceriler açısından mühendislik bölümleri arasında bir fark olup olmadığını araştırmaktır.Matematik konuları ve becerilerinin önem derecelerinin belirlenmesi amacıyla, farklı üniversitelerden değişik düzeydeki üniversite öğretim elemanlarına hem ulusal lise matematik müfredatındaki hem de Uluslararası Bakalorya Diploma Programı'ndaki (IBDP) matematik konuları ve becerileri hakkındaki düşüncelerini belirtmeleri için Likert ölçeği içeren bir anket kullanılmıştır. Bu çalışmadan çıkan en önemli sonuç üniversitelerdeki belirli mühendislik bölümleri için tasarlanmış paket eğitim programları liseler için de tasarlanabilir ve mühendislik bölümleri için gerekli ana konular erken sınıf düzeylerine eklenebilir. Bununla birlikte IBDP'den bazı konuların da Milli Eğitim Bakanlığı (MEB) müfredatına eklenmesi düşünülmelidir.

Anahtar kelimeler: Matematik müfredatı, matematik konuları, mühendislik eğitimi, matematiksel beceriler, farklılaştırılmış müfredat

ACKNOWLEDGEMENTS

I would like to express my deepest gratitude to my supervisor Asst.Prof.Dr. İlker Kalender for his invaluable support and guidance throughout the study. I also thank him for his understanding and encouraging attitude as well as his effort and assistance.

I would like to express my special thanks to Prof. Dr. Cengiz Alacacı who provided me full support for this study with his valuable comments and contributions. He also never neglected to help me throughout the study. I also would like to express my gratitude to Asst.Prof.Dr.Sencer Çorlu who shared his wisdom with me, helped and supported throughout the study.

I would like to acknowledge and offer my sincere thanks to Prof. Dr. Ali Doğramacı and Prof. Dr. M. K. Sands at Bilkent University Graduate School of Education who supported me throughout my masters program. I am also indebted to many of instructors in the Graduate School of Education, to support me during all the process of the thesis. I wish to thank Prof. Dr. Alipaşa Ayas, Asst.Prof. Dr. Necmi Akşit and Asst.Prof. Dr. Robin Martin for all the support they provided. I would also like to thank Aysun Yıldız who proofread my thesis.

Finally, my heartfelt thanks go to my parents who makes my life meaningful with their endless and worthless love and support.

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CHAPTER 1: INTRODUCTION

Introduction

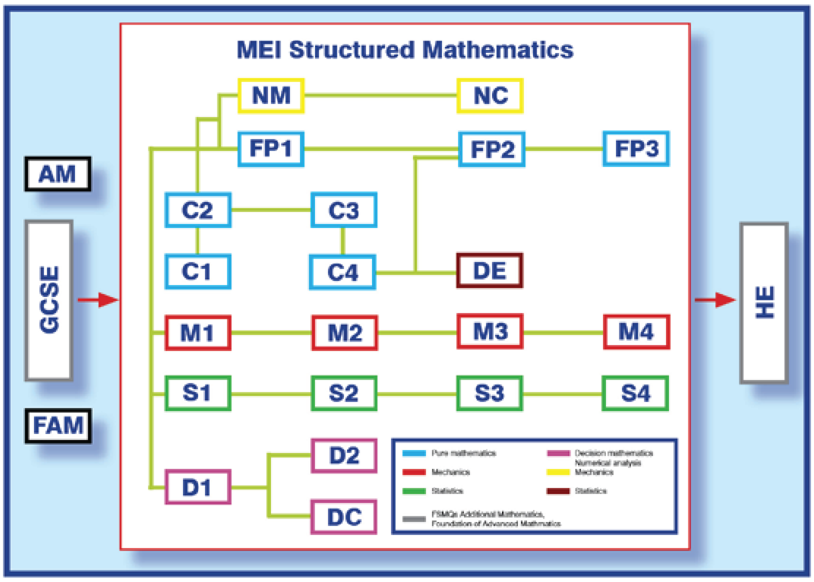
The need for reforms in K-12 education in Turkey has been a topic of discussion among educators, policy makers, academicians, and other stakeholders. Over the past decade, several curriculum reforms have been introduced to achieve mainly two goals: (a) to improve students' literacy skills in core subjects; mathematics, science, and reading; and (b) to adapt Turkish education system according to the needs of information age. The last structural reform, 4+4+4, sought to achieve these two goals. According to MoNE (2012), the new curriculum reform gave opportunity to students to have a more flexible environment and curriculum. Besides, students had an education system that gives chance all members to make decisions according to their interests, abilities and needs. The rationale for the reforms were also in parallel with these goals including Turkish students' low performance in international studies such as the Program for International Student Assessment (PISA, 2013) (Berberoğlu & Kalender, 2005; Alacacı & Erbaş, 2010) and the Third International Mathematics and Science Study (TIMSS, 2013) (Berberoğlu & Kalender, 2005) as well as in nationally-administered examinations such as Student Selection Examination (SSE). While PISA is related to mathematics literacy which refers to the ability to use mathematical knowledge and skills in daily life, TIMSS is conducted to measure science and mathematics knowledge. Apart from the internationally administered examinations, there is a relationship between SSE results and PISA results in terms of mathematics. The schools that have higher mathematics scores in SSE tend to get higher scores in PISA (Berberoğlu & Kalender, 2005).

Turkey attended PISA for the first time in 2003. The first cycle of PISA was between the years 1997-2000. Turkey did not attend it and missed the opportunity to assess the education system at an international level (Yalçın, 2011). According to the results of PISA in both 2003 and 2006, Turkey's scores were below the average in terms of mathematics and half of the 15 years old students' results were just at a basic mathematics level (Alacacı & Erbaş, 2010). PISA 2009 results were better than those of previous years. Since 2009, MoNE have been making some reforms in Turkish education system considering the results of the international examinations and needs.

Turkish Board of Education reformed school curricula in Turkish education system in 2005 (Aydın, Çorlu, & Ayas, in press). Among the objectives of these reforms, as appeared in Akşit (2007), are "reducing the amount of content and number of concepts, arranging the units thematically..." (p.133). Reform efforts were also clearly stated in the new strategic plans of The Ministry of National Education (MoNE, 2009). According to the 2010-2014 Strategic Plan, international examination results will be considered as a benchmark to improve the quality of outputs in Turkish education system and to assess curricular reforms (MoNE, 2009). These new reforms will have implications on mathematics curriculum, as well.

Despite all these changes in the national curriculum, there are still many problems in Turkish education system. As evidenced by the result of examinations such as SSE, PISA and TIMSS, there is a need for reforms in K-12 education in Turkey. Turkey and several other countries such as Germany, Canada, and UK worked on measures and practices according to 2003, 2006, and 2009 PISA results to make progress and to solve the problems in their education systems (Yalçın, 2011).

The education systems of such countries as Germany, Canada, and UK can help us to understand the abovementioned problems, for Germany and Canada were among the countries that had higher scores than Turkey; Germany ranked eight and Canada six in PISA 2009 in the field of mathematics (Özenç & Arslanhan, 2010). Turkey was again below average in the same exam (MoNE, 2010). Moreover, having a differentiated curriculum in high schools, German's educational system was built based on the principle of giving opportunity to students according to their interests and abilities. Turan (2005) indicated that Germany Education system was built on the principle that was about "providing student the most appropriate learning environments according to their interest and abilities". In addition to the education system in Germany, Canadian Education system was built on the idea of encouraging students to be critical and creative thinkers. All students are special therefore students are provided with an educational environment that gives them an opportunity to choose their areas in the consideration of their interests and abilities (Güzel, Karakaş, & Çetinkaya, 2010). Additionally, the UK education system was also built on the principal that giving opportunity to the students according to their interest and abilities before higher education (Lee, 2010). In the study of understanding the UK mathematics curriculum pre-higher education, the students have chance to choose different mathematics topics before higher education. The Figure 1 shows the UK mathematics curriculum pre-higher education.



Note: AM is Additional Mathematics, FAM is Foundations of Advanced Mathematics, NM is Numerical Methods, NC is Numerical Computation, FP is Further Pure Mathematics, C is Core Mathematics, DE is Differential Equations, M is Mechanics, S is Statistics, D is Decision Mathematics, DC is Decision Mathematics Computation

Figure 1. The UK mathematics curriculum pre-higher education (Lee, 2010)

In addition to that, the new 4+4+4 structural reform in Turkish education system also aims at giving opportunities to students for choosing their careers according to their interests and abilities in high schools (MoNE, 2012). In the consideration of these ideas, these changes in curriculum will require the re-assessment of the topics for high school mathematics curriculum. ‘Reducing the amount of content’, which is one of the new mathematics curriculum objectives, can be considered in parallel to the differentiating curriculum issue.

Background

One of the commonly known philosophies, social constructivist approach, has an important role in mathematics curriculum. As Ernest (1999) said, “The social constructivist thesis is that mathematics is a social construction, a cultural product, fallible like any other branch of knowledge” (p.2). In other words, mathematical knowledge is the product of social life. As social life changes, the requirements for every single discipline also changes, especially the engineering disciplines.

Mathematics is fundamental not only for life sciences but also for engineering fields. The main purpose of this study is to determine mathematical topics and skills for high school mathematics curriculum to better prepare students for further engineering education. Purposes for teaching mathematics at secondary level include preparing students to think critically, and making them utilize mathematics in various parts of their lives (NCTM, 2000; Khan & Taherkheli, 2011). According to Cockcroft Report (1982), high school mathematics curriculum should address the mathematical needs of adult life the mathematical needs of areas of employment (e.g., manufacturing industry, clerical work, retail trade, agriculture, construction industry) and the mathematical needs of further and higher education in technical and social fields. Mathematical knowledge and skills are important to become successful in engineering fields. It is important to find out if students acquire mathematical knowledge in high school as demanded by engineering professors and staff university education as such. Güner and Çomak (2011) stated that one of the significant subjects is mathematics for engineering education. If a student enrolls in engineering departments without basic mathematical knowledge and skills, these students are called mathematically “at-risk”. Engineering departments should have a strong side of mathematical structure and basic sciences (Gençoğlu & Gençoğlu, 2005, p.273).

All in all, knowledge of mathematics is essential for the study of engineering and of most other technological subjects.

Problem

"Directing students according to their interest and abilities" (MoNE, 2012) is one of the objectives stated by Turkish curriculum and several other curricula such as German and Canadian. Hence, it seems that all students do not need to study the same mathematical topics, as their future plans are most likely to be different. As a result of new reforms in Turkish education system, new curriculum changes will probably bring a differentiated curriculum in high schools. Through such curricula, students follow courses related to the higher education programs they wish to study. At that point, it is of importance to determine the topics in high school curriculum according to the higher education. A review of the literature shows that there has not been enough research about determining the mathematical topics and skills that should be included in high school mathematics curriculum to better prepare students for computer, and electrical-electronics engineering in Turkey.

There is a direct relationship between being successful in engineering fields and the level of high school mathematics knowledge of engineering students. The importance of the relationship between high school mathematics curricula and university education can also be seen in the study of Crowther, Thompson, and Cullingford (1997). They stated that, in England, a high drop-out rate and failure rate of engineering were investigated and the results were interesting since 38% of engineering students think that they do not come to engineering departments with sufficient mathematical knowledge from high school. Additionally, Mustoe and Lawson (2002) suggested that coming to engineering departments without learning basic high school mathematical topics will make educational life difficult to students to understand and use advanced mathematical topics in engineering departments.

Purpose

The purpose of this study is to explore if there is a difference among the engineering departments based on the topics and skills that students are expected to gain in high school, by investigating importance levels of the topics and skills. By this way, mathematics topics and skills, which exist and/or should be in high school mathematics curriculum to related high school curriculum to higher education, are expected to be defined. For identifying importance levels mathematical topics and skills, university staffs with different academic rankings from different universities were asked to express their opinions about topics and skills in high school mathematics curricula of both MoNE and International Baccalaureate Diploma Program (IBDP, 2006). IBDP curriculum was included to the present study since it has several topics that do not exist in the MoNE curriculum. Thus, the present study seeks to identify the importance levels of mathematics topics and skills for different engineering departments in a comparative manner across departments, universities and academic ranks. Moreover, open-ended responses including suggestions and/or comments for the topics and skills from the participants were the focus of the study. Results of the present study are expected to provide an insight when determining mathematical topics and skills that should be included in high school mathematics curriculum for computer and electrical-electronics engineering fields in Turkey.

Research questions

This study will focus on the following question:

Based on the opinions of university staff in engineering departments, the mastery of which topics and possession of which mathematical skills are important in high school mathematics curriculum to effectively prepare students for university education in engineering fields?

To answer this question, the following five sub-questions will be investigated:

1. What are the topics of high school curricula that are needed for engineering education in university?
2. What are the mathematical skills that are needed for engineering education?
3. What are the differences between engineering departments in terms of importance levels of mathematics topics and skills given in high school?
4. What are the differences between universities with engineering departments in terms of importance levels of mathematics topics and skills given in high school?
5. What are the differences among academic staff with different ranks in engineering departments in terms of importance levels of mathematics topics and skills given in high school?

Significance

There have been a few research studies about the differentiation in topics and skills in high school according to requirements of university education in Turkey. If a student wants to be a doctor, s/he will probably not need some mathematics topics, and some other mathematics topics are more significant for him/her. In this study, some of these topics for electrical-electronics and computer engineering were investigated because these fields of engineering are the most popular fields of engineering in Turkey (TMMOB, 2005; ÖSYM, 2012). Mathematical knowledge and skills are important to become successful in such departments. Thus, it is important to find out if students acquire mathematical knowledge in high school as demanded by engineering professors and staff university education as such. Besides, mathematics is one of the most important subjects for engineering education (Güner, 2008). In the School of Engineering, students who enroll in university without basic mathematical knowledge and skills were considered as mathematically ‘at-risk’ (Güner & Çomak, 2011). Engineering departments should have a strong side of mathematical structure and basic sciences (Gençoğlu & Gençoğlu, 2005). If students learn only how to solve problems in a multiple choice format, then they have difficulty in exams and research papers as well as projects in which they need to use mathematics flexibly and creatively (Gençoğlu & Cebeci, 1999). Knowledge in mathematics is essential for the study of engineering and of most other technological subjects (Cockcroft, 1982). Therefore, determining the high school mathematics topics for the differentiated curriculum will be helpful for policy makers, curriculum developers, educators and teachers since these topics could help students to further their education in computer, and electrical engineering fields with a better preparation in Turkey.

Definition of key terms

Mathematics has a significant role for many fields and real life. The main purpose of this study is to determine mathematics topics and skills for high school mathematics curriculum to prepare students better for further engineering education. Mathematics has many definitions. Nevertheless, mathematics can be defined as a language that consists of a set of numbers, letters, and symbols. However, according to Cockcroft (1982), mathematics can be defined as showing knowledge in many ways, “not only by means of figures and letters but also through the use of tables, charts and diagrams as well as of graphs and geometrical or technical drawings" (p.1).

In teaching mathematics, students need some skills to learn effectively. Some educators also believe that these skills are significant for learning topics. According to Marcut (2005), "in order to learn mathematics through problem solving, the students must also learn how to think critically." (p. 60). Critical thinking skills can be defined as thinking in a different way to understand deeper and interpret the information on one's own words with the help of questioning. According to Fisher (2001), critical thinking enables students "to transfer to other subjects and other context" (p.1). Critical thinking skills can also be defined as expressing ideas systematically to evaluate the validity of something argument, expression, news, or search.

Mathematical problem solving is a kind of mathematical skill that is related to using effectively mathematical concepts and rules for solving unordinary problems.

Mathematical modeling can be defined as constructing models which can predict and explain the problems of science, social science, engineering, economics etc. with using mathematical language and concepts.

Mathematical reasoning is an important skill that can be defined as understanding the logic behind mathematical rules, generalizations and solutions and preventing memorization of formulas.

Mathematical communication is expressing mathematical ideas with the help of standard mathematical symbols and terms that other people can understand.

Mathematical relations can be defined as making connections with mathematical concepts, mathematics and other science fields, mathematics and real life.

Mathematical representations are multiple representations of concepts for instance function, with methods such as algebra, graph, table, diagram etc. and making connections and transitions between them.

Analytical reasoning skills are partitioning parts and relations between parts abstractly to understand the process of a whole.

CHAPTER 2: REVIEW OF THE LITERATURE

Introduction

Mathematics plays a significant role in many fields and real life. In this review, the purpose is to give information about types of mathematics curriculum such as intended, attained, and taught curriculum and explore social constructivism in mathematics education curricula, mathematics required by technical fields, academic studies, and education of engineering. This knowledge will be helpful to understand the general idea of high school mathematics curriculum to prepare students better for engineering education. According to Khan and Taherkheli (2011), the purposes of teaching mathematics at secondary level include "preparing students to think critically" and "utilizing it in different fields of life" (p.189). In addition to that, "secondary education is where students begin to learn the mathematics they will need for careers as well as the mathematics required for effective citizenship" (National Research Council, 1989, p.48). On the other hand, according to Cockcroft Report (1982), that investigates the school mathematics in work and life; why we should learn mathematics, high school mathematics curriculum should address; a) the mathematical needs of adult life, b) the mathematical needs of areas of employment (e.g., manufacturing industry, clerical work, retail trade, agriculture, construction industry), and c) the mathematical needs of further and higher education in technical and social fields.

According to Gençoğlu and Cebeci (1999), there are some elements and steps for an education system to provide the best education for students, which are to determine the needs, identify the time, content and procedures of the system, choose appropriate tools, and analyze the needs and benefits of the education system. While implementing these steps, the key element is to determine the topics that students should learn for the future. On the other hand, according to Macintyre and Hamilton (2010), "Increase of participation levels and students' success within mathematics is challenging for educators and policy makers" who believe engagement with the subjects is important. They also indicated that choosing relevant topics for students' lives and appropriate for learners' future occupations and career plans is helpful to increase engagement with the subjects.

In this literature review, the purpose is to present a theory of mathematics curriculum and the factors related to the curriculum and topics. Therefore, conceptions of the theory of mathematics curriculum will firstly be examined.

Social constructivism in mathematics education curricula

The philosophy of mathematics has been a topic of discussion for years. There are two main perspectives for the philosophy of mathematics that are "(i) absolutist and (ii) conceptual change philosophies of mathematics" (Ernest, 1999, p.2). According to absolutists, mathematical knowledge cannot change and it is certain knowledge (Bishop, 1996; Ernest, 1999; Hall, 2002). On the other hand, according to conceptual change philosophies, mathematical knowledge is the product of social life and it is fallible and it changes (Bishop, 1996; Hall, 2002; Davison & Mitchell, 2008). Social constructivist approach supports the second idea since conceptual change of mathematics requires alteration in the context. According to Ernest (1999), "The social constructivists' main argument is that mathematics is a social construction, a cultural product, fallible like any other branch of knowledge." (p. 2). White-Fredette

(2010) indicated that social constructivism can be applied in teaching and learning mathematics. This theory also is applicable for curriculum since according to social constructivist approach, mathematics is social product and it changes. Therefore, curriculum should also change to serve for a better education system.

Types of curriculum

Curriculum has a significant role in an education system since it can affect the strategies of teaching, topics, and learning objectives. Curriculum is the word that "…comes from the Latin word for course or career. It refers to actual experience; it is not about intentions, but reality" (Kilpatrick, 2009). Besides, Marsh and Willis (1995) stated that curriculum is "all planned learning for which the schools are responsible" (p.9). From this point of view, schools are responsible for implementing the curricula developed by policy makers and educators. As stated earlier, high school mathematics curriculum should address three main points that are the mathematical needs of adult life, areas of employment and further and higher education in technical and social fields. Additionally, mathematical teaching at all level should include opportunities for (Cockcroft, 1982):

> Exposition by the teacher, discussion between teacher and pupils and between pupils themselves, appropriate practical work, consolidation and practice of fundamental skills and routines, problem solving, including the application of mathematics to everyday situations, and investigational work. (p.243)

From this perspective, we can look at high school mathematics curriculum in terms of academic requirements, real life applications, and professional requirements. Furthermore, similar objectives can be seen in the Ministry of Education's educational objectives for secondary education. According to The Ministry of

National Education (MoNE) (2011), "The objective of secondary education is to prepare students for both higher education and a profession or for life and employment in line with their interests and aptitudes." (p. 14).

According to Cuban (1990), "A curriculum of a school is a series of planned events intended for students to learn particular knowledge, skills and values and organized to be carried out by administrators and teachers" (p.221). Considering these ideas, curriculum can be categorised as intended, taught, and attained curriculum.

Differentiating between the types of curriculum

Curriculum can be categorised as intended, taught, and attained curriculum in terms of differentiating. Intended curriculum is the type of curriculum that is a set of objectives to establish a curriculum at the beginning of curriculum plan. The United Nations Children's Fund (UNICEF) sponsored research studies on curriculum called UNICEF-related curriculum projects. According to one of these studies, "The intended curriculum refers to the formal, approved guidelines for teaching content to pupils that is developed for teacher and/or by teachers." (UNICEF, 2000, p.10) According to Kilpatrick (2009), intended curriculum "is not a curriculum itself. Instead, it is a blueprint for a curriculum to be realized." (p. 109) National goals, teachers' perspectives, and political issues have effects on shaping the intended curriculum. MoNE prepares curricula in a way that students and teachers will benefit from. Educators and policy makers also prepare textbooks, teacher guide books, and other written curriculum materials according to intended curriculum (UNICEF, 2000).

In Turkey, there are many objectives for mathematics curriculum. According to Turkish Board of Education; students will be able to i) understand mathematical notations and systems and to use this knowledge in real life and for other goals, ii) express their ideas with the help of mathematical reasoning and mathematical procedures. Moreover, students will be able to i) improve their own problem solving strategies, ii) use these strategies to solve real life problems, iii) enhance the power of searching and using the knowledge, iv) make a connection between mathematics and arts and then v) improve their own aesthetic faculties (TTKB, 2011).

It can be understood from the objectives mentioned above that; the MoNE refers to general statements and situations for mathematics. There are no separate objectives and topics for students who want to go to faculty of engineering, science, education etc. Every student must take same courses at high school regardless of plans about higher education.

On the other hand, according to the Turkish Constitution, stated by Turan (2005), Turkish Education system was built on the principle that was about “directing students according to their interest and abilities” (p.67). However, when other countries’ education systems are investigated, it seems that there are different approaches for mathematics curriculum. For instance, Canadian Education system was built on the idea of encouraging students to be critical and creative thinkers. Besides, all students are special therefore students are provided with an educational environment that gives them an opportunity to choose their areas in the consideration of their interests and abilities (Güzel, Karakaş, & Çetinkaya, 2010). Similarly, German Education system was built on the principle that was about “providing student the most appropriate learning environments according to their interest and abilities" (Turan, 2005, p.67).

Taught curriculum includes formal and informal lessons that are taught by teachers or educators. The difference between taught and intended curriculum is mainly about the role of the teacher. According to Cuban (1990), taught curriculum can be also called "implicit", "delivered" or "operational" curriculum that teachers teach in lessons and use textbooks, chalks and other materials to present content, ideas, and skills. Here, teachers have important role in shaping taught curriculum since teachers' decisions, attitudes and ideas can affect the curriculum.

Attained curriculum is mainly what students learn from the intended and taught curriculum. Students gain knowledge and acquire attitudes through attained curriculum. Therefore, if the curriculum does not include some knowledge, skills, and attitudes, then students will fail to learn them (UNICEF, 2000).

Mathematics required by technical fields

Some technical fields require mathematical skills and knowledge to be successful and understand the studies. In Turkey, computer, and electrical-electronics engineering are the most popular technical fields and these engineering fields have a wide scope of applications in our lives. Mathematical knowledge and skills are important to be successful in those fields. It is important to find out if students come to university from high school with the kind of mathematical education needed to do well at the engineering fields and this need is emphasized for engineering education by professors and engineering students (Güner & Çomak, 2011).

Some occupations require the use of mathematical skills and knowledge. Arithmetical calculations are a common requirement of all kinds of employments. According to Cockcroft (1982), while some professions require mental calculations, some other use division and multiplication, and some occupations require use of time tables, the use of percentages which is common in laboratories and offices. Moreover, some workshops also require the use of percentages, calculators that are also used by people working in laboratories and engineering design offices. Fractions are used widely in engineering fields and other clerical works. The notation of fraction is used in some clerical work and retail trades.

Mathematics in daily life

The role of mathematics in daily life has been gaining significance day by day and at a basic level, we need to be able to count, subtract, divide and multiply. We know that some people should use mathematics in their lives according to their hobbies, interest, and needs. If someone has to count numbers, consult timetables, pay for purchases and so on, then some mathematical skills and knowledge are required to do these works.

Additionally, we use mathematical knowledge and skills in our daily lives and while doing clerical works, occupations, and retail. According to Cockcroft (1982), technical fields will require the use of mathematical skills and knowledge for projects and operations. Furthermore, “Engineering as a profession requires clear understanding of mathematics. Mathematical theories and principles are applied to real life situations” (Zainuri, Nopiah, Asshaari, &Yaacob, 2009, p.202).

Mathematics has a significant role in our daily lives. We use it in many instances such as counting numbers, ordering objects, listing etc. Therefore, for making these works and teaching mathematics, we need to develop some mathematical skills.

Creative thinking skill and quantitative reasoning are the most significant ones. Another important ability is critical thinking. According to Fisher (2001), critical thinking facilitates students' knowledge to "transfer to other subjects and other context" (p.1). These skills are used in our daily lives and other mathematical skills such as problem solving; mathematical reasoning, logical thinking, and analytical reasoning skill have also an important role in our lives. These kinds of skills and knowledge are also important for engineering students (Gençoğlu & Gençoğlu, 2005).

Mathematics as an area of the 21st century skills

Over the past two decades, there has been a great emphasis on teaching *basics* to the students including reading, writing, and mathematics. Therefore, it is time to look at closely, 21st century skills, since these skills have directly or indirectly influences teaching and learning. Educators, curriculum makers, and especially teachers should be familiar with these skills (Larson & Miller, 2011). These skills can be listed as;

- Problem solving, critical thinking, creative thinking, analytical thinking etc.
- Modelling, creativity, collaboration, technology skills
- Core subjects such as reading, mathematics etc.

One of the organizations is Partnership for 21st Century Skills which works for integrating these skills into education. It described these skills to be successful in today's world as a) core subjects (English, reading or language arts, mathematics, economics, science, geography) and 21^{st} Century Themes b) Learning and innovation skills (critical thinking and problem solving, creativity and innovation, communication and collaboration) c) information, media, and technology skills d) life and career skills (Partnership 21^{st} Century Skills, 2009). Similar skills were offered by International Society for Technology in Education ([ISTE] 2007) such as creativity and innovation, critical thinking, problem solving, decision making, communication and collaboration etc.

21^{st} century skills are not new but they are "newly important" since people should be able to find the sources and use different materials to solve the problems (Silva, 2009, p.632). Since they are newly important, all kinds of jobs and fields such as engineering, architecture, medicine etc. require these skills to be successful in today's world (Morgan, Moon, & Barroso, 2008). More specific, engineering for 21^{st} century requires these skills due to its complicated structure and development in technology. According to Beers (2012) 21^{st} century skills: preparing students for their future emphasized that to prepare students for their future lives and careers, they need to deal with real world problems that are engaging and relevant. Science, technology, engineering, and mathematics (S.T.E.M.) projects require students to be active learners who learn by doing. Besides, as a problem solver, students use high level of thinking and combination of all knowledge to come up with a solution of problems (Capraro & Çorlu, 2013).

On the other hand, to understand the importance of 21^{st} century skills for engineers and the position of mathematics among these skills, a close look into engineering education maybe appropriate. Kyllonen (2012) stated in his study of measurement of 21^{st} century skills within the common core state standards, the mathematics is as important as other 21^{st} century skills. According to the same study 64% 2-year college graduates believe that mathematics is important for 21^{st} century and today's workplace. In addition to that, other research studies have shown similar findings such as National Academy of Sciences (2011) and Boston Advanced Technological Educational Connection (BATEC) (2008) stated in Kyllonen (2012).

Kyllonen (2012) also stated that "it is clear that educators and employers claim that 21^{st} century skills are important for the schools to develop and for students to possess in order to be successful in the 21st century workplace" (p.18). In this regard, 21^{st} century skills are important both preparing students for the future and 21^{st} century workplace. Moreover, we see similar skills in Turkish curriculum objectives. Problem solving, analytical thinking, modelling, critical thinking, and finding new ways to solve real world problems are some of the objectives stated by MoNE for new mathematics curricula.

Besides, PISA tries to assess whether students gained these skills or not. According to the report of National Research Council (2011) "PISA 2012 assessment of problem-solving competency will not test simple reproduction of domain-based knowledge, but will focus on the cognitive skills required to solve unfamiliar problems encountered in life and lying outside traditional curricular domains" (p.25). From this perspective, solving real life problems and problem solving skills are also important for PISA.

To sum up, 21^{st} century skills can be listed as problem solving, critical thinking, modelling, analytical thinking, core subjects such as reading, mathematics etc., creative thinking. All these skills are also required by computer and electrical-electronics engineering (Bureau of Labor Statistics, 2013).

Engineering education

Engineering can be defined as a process of using knowledge of mathematics, natural sciences and social sciences and applying this knowledge to create new products for human use. It can be also defined as "a human activity aimed at creating new artifacts, algorithms, processes and systems that serve humans" (MIT, 2012). The more explicit definition of engineering is that "the application of scientific and mathematical principles to practical ends such as the design, manufacture, and operation of efficient and economical structures, machines, processes, and systems" (Prendergast, 2012, p.30). Additionally, engineering is a profession that is based on technology, science, and mathematics combining all of these fields to solve the real life problems and make life easier for people (Morgan, Moon, & Barroso, 2008). On the other hand, engineering can be defined as combinations of the fields of mathematics, science and technology to create new products and solve real life problems (Zainuri, Nopiah, Asshaari, &Yaacob, 2009). Engineering is "the art of applying scientific and mathematical principles" (Sevgi, 2004). Besides, engineering requires clear understanding of mathematics, using mathematical knowledge appropriately (Pyle, 1991). Based on these explanations and definitions, it can be stated that one of the important elements for engineering education is mathematics as one of the significant subjects is mathematics for engineering education. Engineering departments should have a strong side of mathematical structure and basic sciences (Gençoğlu & Gençoğlu, 2005, p.273). Besides, "Knowledge of mathematics is essential for the study of engineering and of most other technological subjects" (Cockcroft, 1982, p.54).

Additionally, to predict academic performance in engineering, some special methods such as high school exam scores of the engineering students (Winter & Dodou, 2011), support vector machines (Güner & Çomak, 2011), the number of true mathematics questions in SSE of students who choose engineering fields (Çetin & Mahir, 2006), freshman electrical engineering students' level of mathematics knowledge from high school (Güner, 2008) revealed that there is a direct relationship between being successful in engineering fields and the level of high school mathematics knowledge of engineering students (Lee & Lee, 2009).

In addition to these ideas, education of engineering has been a discussion topic among educators, engineers, and instructors from engineering departments in recent years (Allen, 2000; Kent & Noss, 2000). Furthermore, in order to educate 21st century engineers, student center pedagogy and project based learning should be considered since these approaches require students to think critically, analytically, and higher order thinking skills (Capraro & Çorlu, 2013). In a research study conducted by engineering council in England, with a comparison of the last 10 years students' mathematics achievement, the study showed that the last 10 years students' mathematical knowledge have been decreasing day by day (Engineering Council, 2000). On the other hand, there is a direct relationship between students' success in an engineering department and level of mathematical knowledge. In a study on predicting academic performance in engineering using high school exam scores it was found that mathematics had the highest correlation with the first year GPA (Winter & Dodou, 2011). In addition to that, the importance of the relationship between high school curricula and university education can also be seen in the study of Crowther, Thompson, & Cullingford (1997). They stated that, in England, a high drop-out rate and failure rate of engineering were investigated and the results were interesting since 38% of engineering students think that they do not come to engineering departments with sufficient mathematical knowledge from high school. Additionally, Mustoe & Lawson (2002) suggested that coming to engineering departments without having basic high school mathematical topics will make it difficult for the students to understand and use advanced mathematical topics in engineering departments.

The research study conducted by Güner (2008), which was about freshman students' level of mathematics knowledge at an electrical engineering department, showed that nearly all high school mathematics topics were found important to graduate from engineering department. In the same research study, students reported, at the beginning of their university life, that they come to the engineering departments from high school without having enough mathematical knowledge. They also stated that they know the mathematics topics from high school that were asked in the Student Selection Examination (SSE). Therefore, they have enough mathematical knowledge about these topics. On the other hand, students come to the engineering departments without having any idea about the important topics for engineering if these mathematics topics were not asked in the SSE. Integral, derivative, limit, application of derivative, drawing function graphs, linear algebra, quadratic equations, logarithm, trigonometry, sine, cosine rules, complex numbers, probability, continuity, sequences, properties of shapes in space, and continuity of functions are among these topics (Güner, 2008). At the last grade level of university, students mainly indicated that the topics listed above were considered as important in their professional lives. Based on the results of the study, it can be argued that in the mathematics classes at high schools the main focus was on the topics asked in SSE, rather than the ones which are required in university. However, based on some recent changes in item coverage in SSE, the topics are included in SSE; therefore students may give more importance to these topics. On the other hand, there is no study investigating the importance of topics after the new regulation in the literature.

Electrical and electronics engineering

Electrical-electronics engineers analyse the requisites and costs of electrical-electronics systems. These types of engineers plan, modernize, test, and manage the manufacturing of electrical-electronics equipment such as "electric motors, radar and navigation systems, communications systems, or power generation equipment. Electrical-electronics engineers also design the electrical systems of automobiles and aircraft". This engineering field is close to computer engineering. Taking courses in physics and mathematics-algebra, trigonometry, and calculus are beneficial for high school students interested in studying electrical or electronics engineering (Bureau of Labor Statistics, 2013).

Among the topics covered in the syllabus of departments of electrical-electronics engineering, there are topics such as probability, statistics, statistical graphing, quadratic equations, trigonometric functions, mathematical modeling (Bilkent University, 2013; METU, 2013). Similar topics were stated in report of U.S. Department of Labor.

Computer engineering

As one of the popular engineering fields, computer engineering do research, design computers, and find new ways to use them in business. In addition, they deal with problems in business, science, and engineering and provide solutions using computers (Bureau of Labor Statistics, 2013). Among the topics covered in the syllabus of departments of computer engineering, there are topics such as fractions, decimals, basic statistics, basic problem solving etc. from basic mathematics; formulas, equations, quadratic equations, operations with polynomials etc. from algebra; circles, transformations, angle measurements etc. from geometry; calculus and higher mathematics, computer use, computer programming etc. from other topics (Bilkent University, 2013; METU, 2013). Similar topics were covered in report of U.S. Department of Labor (Bureau of Labor Statistics, 2013).

Summary

As discussed in the subsections of this chapter, mathematics knowledge and skills obtained by the literature such as problem solving, critical thinking is an integral part of engineering education in 21st century. In this review of the literature, social constructivism in mathematics education curricula, curriculum types, mathematical knowledge and skills for real life and technical fields were examined. Moreover, many research studies and information were explored that emphasized the significance of mathematics for engineering. However, there is no study on mathematics topics and skills in high school mathematics curricula in Turkish secondary education, investigating importance and necessity levels of the topics for engineering education in universities. Such a study may provide an insight for the feasibility of differentiated curriculum for engineering departments in Turkish higher education.

CHAPTER 3: METHOD

Introduction

In this chapter, issues related to the methodology of the study will be presented such as research design, context, participants, instrumentation, method of data analysis, etc. The present study investigates the importance levels of high schools mathematics topics and skills required for different engineering departments in higher education. By this way, scientific evidence about differentiation of curricula with respect to different departments in higher education is sought.

Research design

The present study uses the survey method with a cross-sectional research design. By this way, participants are asked their opinions at one time from a predetermined sample (Creswell, 2003). To obtain information from the sample, a close-ended survey including 49 mathematics topics and 8 mathematical skills were prepared and the participants from the universities were asked to rate importance levels of the topics using a 5-points Likert Scale. The questionnaire was used to gather quantitative data with a cross-sectional research (Creswell, 2003).

Context

This research was conducted in selected universities from Ankara, which have both computer and electrical-electronics engineering departments. Computer and electrical-electronics engineering were chosen since these engineering departments require more mathematical skills and knowledge and has been chosen by students who take top scores from Student Selection Examination (ÖSYM, 2012). Besides, these departments were also chosen since electrical-electronics and computer engineering departments are the most popular fields of engineering and they have a wide scope of applications in our lives (TMMOB, 2005). Additionally, mathematical knowledge and skills are important to become successful in engineering fields. It is important to find out if students acquire mathematical knowledge in high school as demanded by engineering professors and staff university education as such. According to Güner & Çomak (2011), mathematics is one of the important subjects is for engineering education. If a student comes to engineering departments without basic mathematical knowledge and skills, these students are called mathematically "at-risk". Moreover, engineering departments should have a strong side of mathematical structure and basic sciences (Gençoğlu and Gençoğlu, 2005). Considering these ideas, there could be needed mathematics topics and skills from high school mathematics curriculum to effectively preparation.

Participants

This research was conducted with (*n*=72) academic staff including research assistants, doctors, assistant, associate and full professors, in the departments of computer and electrical-electronics engineering at Bilkent University and Middle East Technical University (METU) in Ankara. Thirty-five academicians from Bilkent University and 37 academicians from METU participated in this study. These academicians, who currently work at Bilkent University and METU, were 18 professors, 18 associate professors, 13 assistant professors, 6 doctors, and 17 research assistants. There were 42 academicians from computer engineering and 30 academicians from electrical and electronics engineering. Table 1 presents distributions of the participants with respect to university, departments and academic ranks:

Table 1
Participants

Departments		Ranks	University Bilkent	METU	Total
Computer Engineering		Professor	4	5	9
		Assoc. Prof.	5	4	9
		Ass. Prof.	6	2	8
		Dr.	2	3	5
		Research Ass.	8	3	11
	Total		25	17	42
Electrical-Electronics Engineering		Professor	5	4	9
		Assoc. Prof	4	5	9
		Ass. Prof.	1	4	5
		Dr.	0	1	1
		Research Ass.	0	6	6
	Total		10	20	30

The present study focused on the responses of academic staff about the mathematics topics and mathematical skills that are required for computer, electrical-electronics engineering since the academic staff in these engineering departments teach the lessons and they conduct research studies in the field of computer and electrical-electronics engineering.

Instrumentation

The aim of this study was to explore the importance of mathematical topics and skills which should be included in high school mathematics curriculum to better support university education in computer and electrical-electronics engineering in Turkey. Additionally, this study tried to identify high school mathematics' topics that are of similar importance both for computer and for electrical-electronics engineering at the same time. Therefore, the topics were selected by using national mathematics curricula of MoNE and International Baccalaureate Diploma Program (IBDP) by considering general headings of the topics without going into subtopics under them.

The questionnaire was prepared in the consideration of Turkish mathematics curriculum and IBDP mathematics curriculum. Almost all topics from Turkish mathematics curriculum were chosen for the questionnaire. The rest of the topics which are finite random variables, statistical distribution (binomial, Poisson, chi-squared, and normal distributions), Bayes theorem, significance and hypothesis testing, correlation and regression, and interest/depreciation/cost were chosen from IBDP curriculum since these mathematics topics were not included in Turkish mathematics curriculum. After selecting the topics, a questionnaire including Likert scale items (*1: Not important at all; 5: Very important*) was developed with the help of an expert from Turkish Board of Education. Additionally, 8 skills considered to be required for engineering education in university were also included to the present study. These skills were chosen considering the national mathematics curriculum objectives (TTKB, 2011). Thus, two main categories were mathematics topics (49 items) and mathematical skills/abilities (8 items). Mathematics topics and mathematical skills list were given at the Table 2. In addition, participants were allowed to express their ideas about the topics. This provided to the researcher to collect qualitative data about the topics and skills/abilities that cannot be expressed in terms of by giving scores from 1 to 5. However, the participants did not make any comments about the topics and skills. The questionnaire developed for the purpose of this study is placed in Appendix A.

Table 2
Mathematics topics and skills

9^{th} grade mathematics topics

- Logic (truth tables, propositions etc.)
- Mathematical proof methods (Induction, proof by contradiction, etc.)
- Sets (and operations with sets)
- Relations (relations between sets)
- Concept of function (domain and range sets of functions, operations on functions)
- Modular arithmetic (the numbers that are not in 10 base)
- Exponential numbers and root numbers
- Divisibility of integers
- Rate/proportion
- Vectors in analytic plane, operations and vectors
- Line and circle properties in the analytic plane
- Distance and applications in analytic plane
- Synthetic geometry: point, line, angle, ray, plane, space
- Synthetic geometry: angles and areas of triangles and polygons
- Cylinder, cone, sphere, prism, pyramid and their properties
- Tessellations on the plane (Escher's drawings)

10^{th} grade mathematics topics

- Polynomials (operations on polynomials and factorization)
- Quadratic equations and functions
- Trigonometric ratios (sine, cosine, etc.)
- Trigonometry (acute angle ratios, trigonometric functions, compound angle formula, trigonometric equations)
- Similarity theorems for triangles
- Transformations on the plane (translation, revolution, reflection)
- The proof of theorems in geometry

11^{th} grade mathematics topics

- Complex numbers
- Exponential equations and functions
- Logarithmic equations and functions, natural logarithm
- Proof by induction and proof methods
- Sequences (arithmetic and geometric sequences)
- Matrices, matrices operations and determinants
- Linear equation systems and applications
- Counting methods (permutation and combination)
- Pascal triangle and Binomial expansion
- Analytical investigation of conics (parabola, hyperbola and ellipse)
- Circular region and area of circular region, the angles of a circle, circumference of a circle
- Basic probability concepts (experiment, output, sample, conditional probability, independent and dependent events and others)

Table 2 (Cont'd)
Mathematics topics and skills

- Statistics - Data presentation (graphs such as column, line, box, scatter, histogram etc. graphs)
- Statistics - central tendency and dispersion

12th grade mathematics topics

- Limit and continuity
- Drawing and interpreting functions graphs
- Derivatives and their application
- Integration (Indefinite integrals, definite integrals, application of integrals)
- Vectors in space (three dimensional), operations and vectors
- Plane in space and analytic properties

IBDP mathematics topics

- Finite random variables
- Statistical distributions (binomial, Poisson, chi-squared, and normal distributions)
- Bayes theorem
- Significance and hypothesis testing
- Correlation and regression
- Interest, depreciation and cost

Mathematical Skills

- Mathematical problem solving (ability to apply mathematical concepts and rules effectively in order to solve unordinary problems)
- Mathematical modeling (ability to construct a mathematical models satisfying and explaining matters in science, social science, engineering, economics etc. through mathematical language and concepts)
- Mathematical reasoning (ability to understanding the logic behind mathematical rules, generalizations and solutions and ability to go beyond memorization of mathematical formulas)
- Mathematical communication (ability to explain mathematical reasoning process by standard mathematical terminology and symbols the that other people could understand it)
- Mathematical relations (ability to establish connections among mathematical concepts, mathematics and other science fields, mathematics and real life)
- Mathematical representations (ability to demonstrate a mathematical concept in different ways as through algebra, graph, table, diagram etc. ability to make a link between relations and transitions)
- Critical thinking skills (ability to think systematically to evaluate the validity of argument, speech, news, or research)
- Analytical reasoning skills (ability to abstractly be aware of parts and relations among parts in order to understand the process of a whole)

Method of data collection

The participants in computer and electrical-electronics engineering departments were delivered questionnaire by hand. First, an appointment was made via e-mail. After that, they were visited in their room to answer the questions. Some of the participants wanted to give the questionnaire later. Therefore, these participants were visited after to take back the questionnaire. A checklist consisting of the academicians' names of Bilkent University and METU computer and electrical-electronics engineering departments was used to be sure that all academicians were asked to take the questionnaire. The participants were informed about the significance of the study, content, and privacy. Voluntary participation was important and all data were entered into an Excel file.

Method of data analysis

After data were collected from the participants, they were transferred into SPSS. After that, data cleaning was made by removing participants whose data were incomplete. Results given by participants were analyzed in a comparative manner with respect to departments, universities and academic ranks. Since two universities (METU and Bilkent) and two departments, Computer and Electrical-Electronics engineering (CS and EE) were included in the present study, comparisons were made using one sample t-test for the departments and universities. One-way Analysis of Variance (ANOVA) was used to check the differences among academic ranks, which includes 4 ranks. Each analysis (comparisons with respect to departments, universities and academic ranks) were conducted and reported separately in terms of grade levels of the topics (9^{th} to 12^{th} and IBDP). For the mathematical skills, only mean differences in importance levels with respect to the departments were investigated using independent samples t-test. All analyses conducted at an alpha level of 0.05.

Since responses were obtained using a Likert type scale which includes scores from 1 to 5. Originally, these scores are in ordinal scale because equalities of distances between categories cannot be known. In this case, parametric tests such as t-tests and ANOVA cannot be conducted. On the other hand, many research studies revealed that Likert scales could be treated as having interval scales (Baggaley & Hull, 1983; Maurer & Pierce, 1998; and Vickers, 1999). Moreover, distances among categories were considered equal to treat the scores in internal scale, which makes using statistical tests possible. With such an assumption, use of parametric tests is possible, which provide more power (Winter & Dodou, 2010).

Assumptions of the statistical analyses were considered before the tests were conducted. Assumptions of the independent-samples t-test are: (i) independence of the observations, (ii) normality of the two populations, and (iii) equality of variances of two populations (Gravetter & Wallnau, 2009). The first assumption is considered to be met by random sampling. For the second one, normality assumption, literature shows that t-tests are robust to the violations against the normality assumption (Rasch & Guiard, 2004). Therefore, for t-tests conducted in the present study, this assumption was not checked. The last assumption, equality of variances, was checked by SPSS. Results for both scenarios (variances are equal and not) were displayed in output by using Welch-Satterthwaite (Hayes, 2012) method to make a correction if variances are not equal. So that even though the equality of the variances is not met, independent-samples t-test can be used. Thus, appropriate SPSS outputs for these types were reported based on the results of the check of that assumption.

The ANOVA has the same assumptions as independent-sample t-test. According to Lindman (1974, p. 33) and Box (1954), the F statistic is quite robust against the violations of the homogeneity assumption. The F test can provide information concerning the group mean difference but special caution should be paid in interpreting the results. Assumption of normality was also shown to be robust against the violation. The study by (Schmider et al., 2010) revealed that power of the ANOVA remained constant under different distributions. Based on the findings reported in the literature, for ANOVA, normality assumptions were not checked for normality. In addition, ANOVA results were reported even if the assumption of equality of variances were not met.

CHAPTER 4: RESULTS

Introduction

The purpose of this study was to explore whether there was a difference between the engineering departments of universities in terms of the topics and skills that students are expected to gain in high school. By this way, mathematics topics and skills, which exist and/or should be in high school mathematics curriculum to related high school curriculum to higher education, are expected to be determined.

In this chapter, results of the statistical analyses are presented. For the grade levels between 9^{th} - 12^{th} and IBDP curriculum, mean differences of importance levels given for the topics with respect to (i) the departments and (ii) universities and (iii) academic ranks were investigated using inferential statistical techniques.

For ease of following, analyses performed on data were presented with respect to grade levels (9^{th} to 12^{th} and IBDP). After results related to mathematics topics were given, those for skills were presented. Topics were abbreviated in the tables, figures, and paragraphs in this chapter. For full names, see Chapter 3, pg. 31. Before conducting one-sample t tests, homogeneity of variances was checked by Levene's tests. For the tables, one of the results produced by SPSS for each t test were reported based on Levene's tests.

9th grade mathematics topics

Differences between departments

Figure 2 shows the differences between means of the 9th grade topics for the departments. For the topics, vectors in analytic plane, tessellations on the plane and concept of function have very similar means across departments. The largest difference exists for logic in favor of computer engineering department. Tessellations on the plane have the minimum mean among the topics

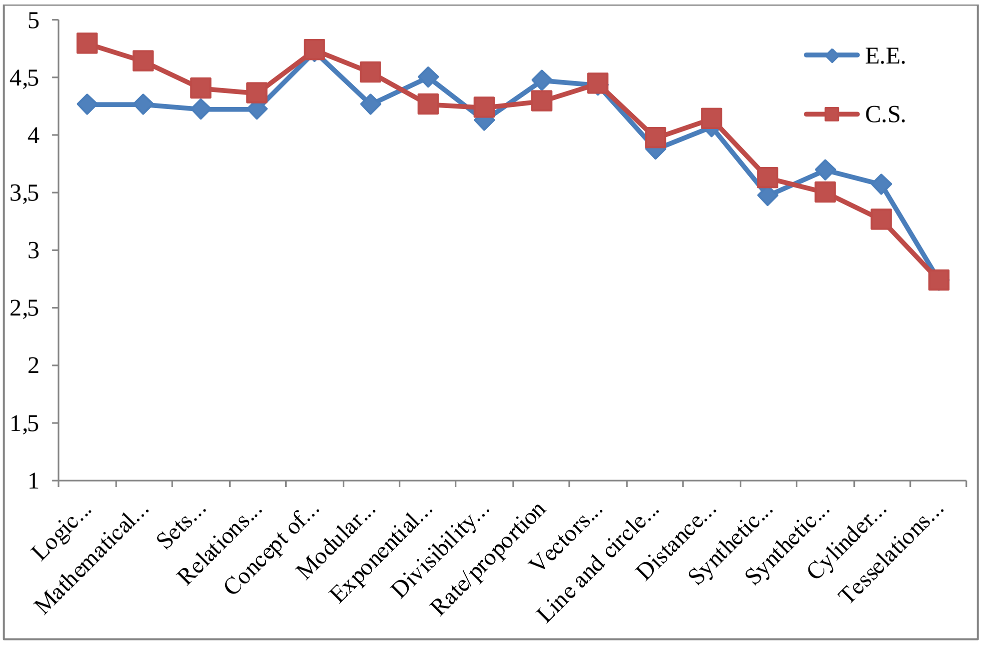


Figure 2. Means of 9th grade mathematics topics for the departments

To investigate the differences between the two departments, independent samples t-tests were conducted for each of the 16 topics covered in 9th grade mathematics curriculum of MoNE. Results were given in Table 3.

Table 3
Independent samples t-test results across the departments for 9th grade topics

Topics	t-test for Equality of Means			
	t	df	Sig. (2-tailed)	Mean Difference
Logic…	-2.82	37.06	.01	-0.52
Mathematical proof…	-2.07	40.84	.05	-0.38

Table 3 (Cont'd)
Independent samples t-test results across the departments for 9th grade topics

Sets…	-0.91	70	.37	-0.17
Relations…	-0.83	69.69	.41	-0.12
Concept of function…	-0.04	70	.97	-0.01
Modular arithmetic…	-1.48	70	.14	-0.28
Exponential numbers…	1.16	70	.25	0.24
Divisibility of integers	-0.56	70	.58	-0.11
Rate/proportion	0.82	70	.42	0.18
Vectors…	-0.12	70	.91	-0.02
Line and circle…	-0.5	70	.62	-0.11
Distance…	-0.37	70	.71	-0.08
Synthetic…	-0.57	70	.57	-0.15
Synthetic geometry…	0.77	70	.44	0.20
Cylinder…	1.32	69.48	.19	0.31
Tessellations…	-0.02	70	.98	-0.01

As can be seen from the Table 3, for 9th grade mathematics topic, logic, $t(37.06) = 0.01$; $p = .01$, has the significant mean difference in importance between the two departments. On the other hand, the topics sets, relations, concept of function, modular arithmetic, exponential/root numbers, divisibility of integers, rate/proportion, vectors in analytic plane, line/circle properties, distance and applications in analytic plane, synthetic geometry, space, angles/areas of triangles/polygons, cylinder, cone, sphere, prism, pyramid and their properties, tessellations on the plane did not have statistically significant mean differences between the two departments.

Differences between universities

Figure 3 shows the mean differences across the universities. The topics tessellations on the plane and cylinder/cone/sphere/prism/pyramid have very low means in both universities compared to other topics. On the other hand, concept of function has the highest mean among the topics.

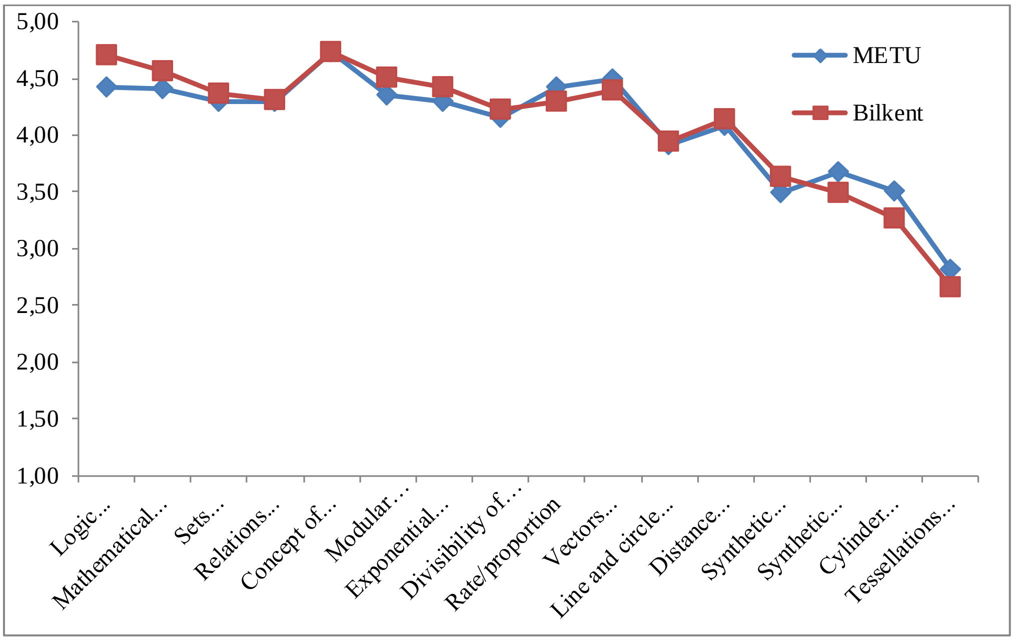


Figure 3. Means of 9th grade mathematics topics for the universities

Table 4 shows the results of independent samples t-tests conducted to investigate the mean differences among the topics across two universities.

Table 4
Independent samples t-test results across the universities for 9th grade topics

Topics	t-test for Equality of Means			
	t	df	Sig. (2-tailed)	Mean Difference
Logic…	-1.69	54.18	.10	-0.28
Mathematical proof…	-1.00	58.38	.32	-0.17
Sets…	-0.40	70	.69	-0.07
Relations…	-0.11	70	.91	-0.02
Concept of function…	-0.12	70	.91	-0.01
Modular arithmetic…	-0.86	70	.39	-0.16
Exponential numbers…	-0.64	70	.52	-0.13
Divisibility of integers	-0.36	70	.72	-0.07
Rate/proportion	0.67	70	.51	0.15
Vectors…	0.55	70	.59	0.09
Line and circle…	-0.11	70	.91	-0.02
Distance…	-0.31	70	.76	-0.06
Synthetic…	-0.54	70	.59	-0.14
Synthetic geometry…	0.74	70	.46	0.19
Cylinder…	1.04	70	.30	0.26
Tessellations…	0.78	70	.44	0.15

According to the results, no significant mean differences were found across the universities.

Differences among academic ranks

To investigate the differences among importance levels assigned to the 9th grade topics across academic ranks, several ANOVAs were conducted. Table 5 presents the results.

Table 5
ANOVA results across the academic ranks for 9th grade topics

Topics		Sum of Squares	df	Mean Square	F	Sig.
Logic…	Between Groups	3.17	4	0.79	1.54	.20
	Within Groups	34.48	67	0.52		
Mathematical proof…	Between Groups	2.07	4	0.52	1.02	.40
	Within Groups	33.91	67	0.51		
Sets…	Between Groups	13.04	4	3.26	7.06	0
	Within Groups	30.96	67	0.46		
Relations…	Between Groups	4.73	4	1.18	2.98	.03
	Within Groups	26.55	67	0.40		
Concept of function…	Between Groups	3.27	4	0.82	4.3	0
	Within Groups	12.72	67	0.19		
Modular arithmetic…	Between Groups	3.20	4	0.80	1.26	.29
	Within Groups	42.45	67	0.63		
Exponential numbers…	Between Groups	11.31	4	2.83	4.59	0
	Within Groups	41.30	67	0.62		
Divisibility of integers	Between Groups	5.98	4	1.50	2.69	.04
	Within Groups	37.30	67	0.56		
Rate/proportion	Between Groups	14.54	4	3.64	5.29	.06
	Within Groups	46.07	67	0.69		
Vectors…	Between Groups	1.90	4	0.48	1.07	.38
	Within Groups	29.88	67	0.45		
Line and circle…	Between Groups	5.39	4	1.35	1.69	.16
	Within Groups	53.27	67	0.80		

Table 5 (Cont'd)
ANOVA results across the academic ranks for 9th grade topics

Distance…	Between Groups	4.09	4	1.02	1.46	.23
	Within Groups	47.02	67	0.70		
Synthetic…	Between Groups	10.41	4	2.60	2.25	.07
	Within Groups	77.37	67	1.16		
Synthetic geometry…	Between Groups	4.33	4	1.08	0.92	.46
	Within Groups	79.18	67	1.18		
Cylinder…	Between Groups	9.52	4	2.38	2.36	.06
	Within Groups	67.59	67	1.01		
Tessellations…	Between Groups	0.47	4	0.12	0.16	.96
	Within Groups	49.52	67	0.74		

According to the results, statistically significant mean differences were found for the topics, sets, $F(4, 67) = 7.05$, $p = .00$, relations, $F(4, 67) = 2.98$, $p = .03$, concept of function, $F(4, 67) = 4.30$, $p = .00$, exponential/root numbers, $F(4, 67) = 4.59$, $p = .00$, and divisibility of integers, $F(4, 67) = 2.69$, $p = .04$.

Additional analyses including multiple comparisons among academic ranks for each topic were also conducted by appropriate post-hoc analyses. Table 6 shows the mean differences across academics in the topics for which statistical significance were found.

Table 6
Post-hoc test results across the academic ranks for 9th grade topics

Rank (i)	Rank (j)	Mean Difference (i-j)				
		Sets[1]	Relations[2]	Concept of Function[1]	Exponential/ root number[1]	Divisibility of Integers[2]
Res. Ass.	Dr.	-0.75	-0.28	-0.26	0.28	0.11
	Ass. Prof.	-0.87	-0.58*	-0.28	-0.83	-0.67*
	Assoc. Prof	-1.08*	-0.51*	-0.59*	-0.84	-0.50
	Prof.	-1.02*	-0.67*	-0.42	-0.34	-0.06
Dr.	Res. Ass.	0.75	0.28	0.26	-0.28	-0.11
	Ass. Prof.	-0.13	-0.30	-0.03	-1.10*	-0.78*
	Assoc. Prof	-0.33	-0.22	-0.33	-1.11*	-0.61
	Prof.	-0.28	-0.39	-0.17	-0.61	-0.17

Table 6 (Cont'd)
Post-hoc test results across the academic ranks for 9th grade topics

Ass. Prof.	Res. Ass.	0.87	0.58*	0.28	0.83	0.67*
	Dr.	0.13	0.30	0.03	1.10*	0.78*
	Assoc. Prof	-0.21	0.07	-0.31	-0.01	0.17
	Prof.	-0.15	-0.09	-0.14	0.49	0.62*
Assoc. Prof	Res. Ass.	1.08*	0.51*	0.59*	0.84	0.50
	Dr.	0.33	0.22	0.33	1.11*	0.61
	Ass. Prof.	0.21	-0.07	0.31	0.01	-0.17
	Prof.	0.06	-0.17	0.17	0.50	0.44
Prof.	Res. Ass.	1.02*	0.67*	0.42	0.34	0.06
	Dr.	0.28	0.39	0.17	0.61	0.17
	Ass. Prof.	0.15	0.09	0.14	-0.49	-0.62*
	Assoc. Prof	-0.06	0.17	-0.17	-0.50	-0.44

[1] Dunnett's C was used since assumption equality of variances did not hold.
[2] LSD was used since assumption equality of variances hold.
* indicates a significant mean difference at .05 level.

Based on the results on the Table 6, for the topic sets significant mean differences were found among (i) research assistant and associate professor, and (ii) research assistant and professor. Importance given by research assistants is significantly lower than those given by associate professor and full professor. For the topic relations, mean of research assistants are significantly lower than all other academic ranks except for doctors. Moreover, for the topic of the concept of function, mean of research assistants are significantly lower than associate professors. For the topic exponential/root numbers, mean of doctors are significantly lower than assistant professors and associate professors. For the topic divisibility of integers, mean of doctors are significantly lower than assistant professors.

10th grade mathematics topics

Differences between departments

The Figure 4 shows the differences between means of the 10th grade topics for the departments. Based on that, the largest difference exists for quadratic equations/functions, trigonometric ratios, and trigonometry in favor of electrical-electronics engineering department. For the topics, transformations on the plane and the proof of theorems in geometry have very similar means across departments.

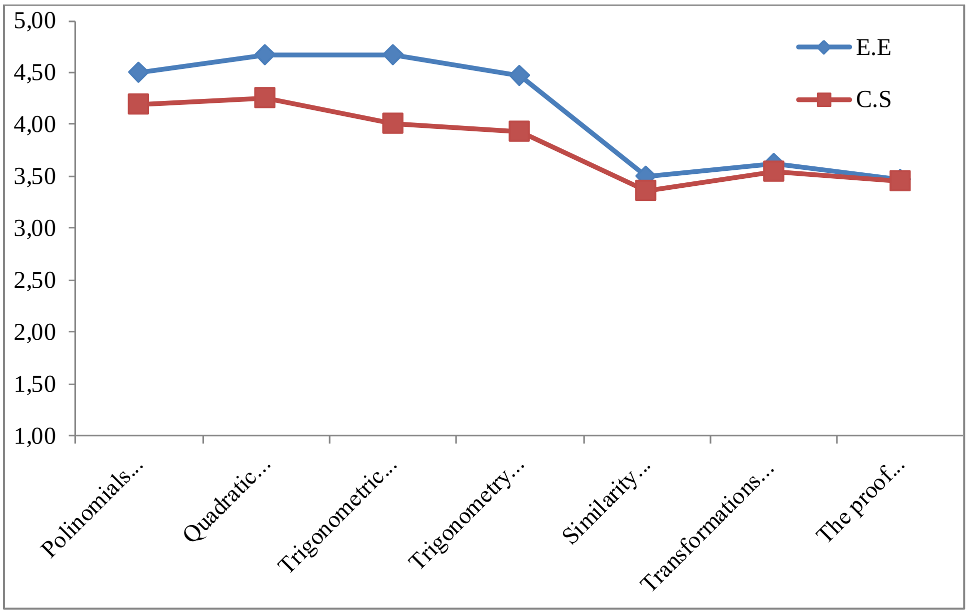


Figure 4. Means of 10th grade mathematics topics for the departments

Independent samples t-tests were conducted to compare mean differences in importance levels 7 topics covered in 10th grade mathematics curriculum of MoNE, between two engineering departments. Results of the analysis were given in Table 7.

Table 7
Independent samples t-test results across the departments for 10th grade topics

Topics	t-test for Equality of Means			
	t	df	Sig. (2-tailed)	Mean Difference
Polynomials…	1.76	70	.08	0.31
Quadratic…	2.55	69.91	.01	0.41
Trigonometric…	3.49	70	.00	0.67
Trigonometry…	2.56	70	.01	0.54
Similarity…	0.56	70	.58	0.14
Transformations…	0.32	70	.75	0.09
The proof…	0.06	70	.96	0.01

As can be seen from the Table 7, for mathematics topics quadratic equations and functions, $t(69.91) = 0.01$; $p = .01$, trigonometric ratios, $t(70) = 0.00$; $p = .00$, and trigonometry, $t(70) = 0.01$; $p = .01$, have the significant mean differences in importance between the two departments. On the other hand, polynomials, synthetic geometry, similarity theorems for triangles, transformations on the plane, and the proof of theorems in geometry have not statistically significant mean differences.

Differences between universities

Figure 5 shows the mean differences across the universities. Based on that the topics similarity theorems for triangles and the proof of theorems in geometry have very low means in both universities compared to other topics. On the other hand, the topic, quadratic equations/functions has the highest mean among the topics.

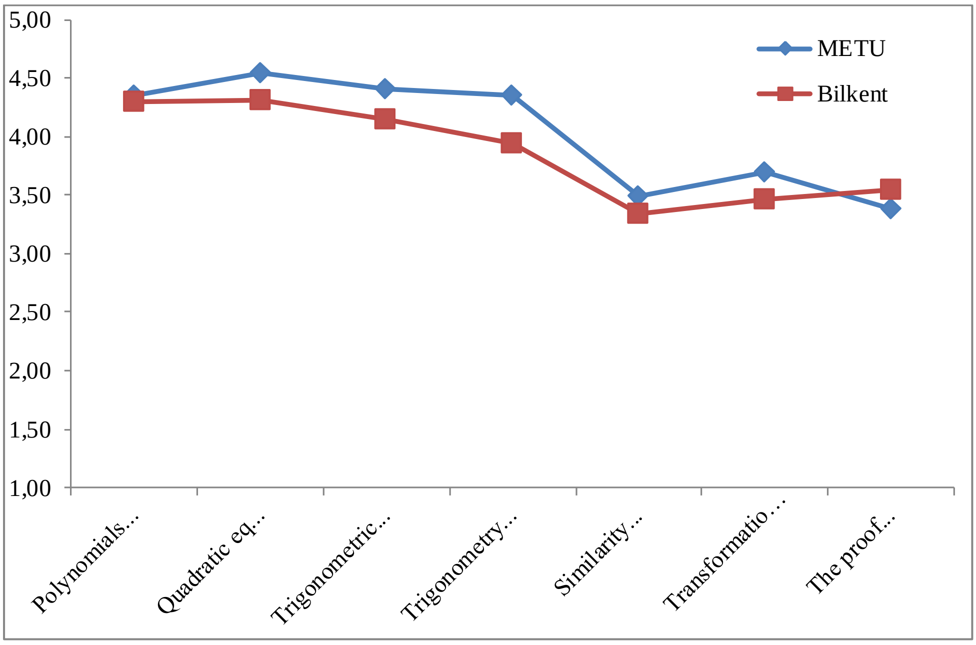


Figure 5. Means of 10th grade mathematics topics for the universities

Table 8 shows the results of t-tests conducted to check the mean differences among the topics across two universities.

Table 8
Independent samples t-test results across the universities for 10th grade topics

Topics	t-test for Equality of Means			
	t	df	Sig. (2-tailed)	Mean Difference
Polynomials…	0.37	70	.71	0.07
Quadratic…	1.33	70	.19	0.23
Trigonometric…	1.30	70	.2	0.26
Trigonometry…	1.93	70	.06	0.41
Similarity…	0.57	70	.57	0.14
Transformations…	0.94	70	.35	0.25
The proof…	-0.66	70	.52	-0.16

According to the results, no significant mean differences were found across the universities.

Differences among academic ranks

To investigate the differences among importance levels assigned to the 10th grade topics across academic ranks, several ANOVA were conducted. Table 9 presents the results of ANOVAs conducted and it includes only the topics for which significant mean differences were found.

Table 9
ANOVA results across the academic ranks for 10th grade topics

Topics		Sum of Squares	df	Mean Square	F	Sig.
Polynomials…	Between Groups	1.90	4	0.47	0.84	.50
	Within Groups	37.76	67	0.56		
Quadratic…	Between Groups	1.97	4	0.49	0.93	.46
	Within Groups	35.68	67	0.53		
Trigonometric…	Between Groups	2.32	4	0.58	0.77	.55
	Within Groups	50.13	67	0.75		
Trigonometry…	Between Groups	3.37	4	0.84	1.01	.41
	Within Groups	55.95	67	0.84		
Similarity…	Between Groups	12.09	4	3.02	2.92	.03
	Within Groups	69.41	67	1.04		
Transformations…	Between Groups	17.79	4	4.45	4.28	.06
	Within Groups	69.71	67	1.04		
The proof…	Between Groups	6.83	4	1.71	1.57	.19
	Within Groups	73.04	67	1.09		

According to the results, statistically significant mean difference was found for the topic similarity theorems for triangles, $F(4, 67) = 2.92$, $p = .03$. Additional analyses including multiple comparisons among academic ranks for each topic were also conducted using LSD for equal variances. Table 10 shows the mean differences across academic in the topics for which statistical significance were found.

Table 10
Post-hoc test results across the academic ranks for 10th grade mathematics topics

Rank (i)	Rank (j)	Mean Difference (i-j) Similarity[1]
Res. Ass.	Dr.	0.22
	Ass. Prof.	-0.89(*)
	Assoc. Prof	-0.78(*)
	Prof.	-0.78(*)
Dr.	Res. Ass.	-0.22
	Ass. Prof.	-1.10(*)
	Assoc. Prof	-1.00(*)
	Prof.	-1.00(*)
Ass. Prof.	Res. Ass.	0.89(*)
	Dr.	1.10(*)
	Assoc. Prof	0.10
	Prof.	0.10
Assoc. Prof	Res. Ass.	0.78(*)
	Dr.	1.00(*)
	Ass. Prof.	-0.10
	Prof.	0
Prof.	Res. Ass.	0.78(*)
	Dr.	1.00(*)
	Ass. Prof.	-0.10
	Assoc. Prof	0

[1]LSD was used since assumption equality of variances hold.
* indicates a significant mean difference at .05 level.

Based on the results on the Table 10, for the topic similarity significant mean difference was found among (i) research assistants and assistant professors, (ii) research assistants and associate professors, and (iii) research assistants and professors. Besides, importance given by research assistants is significantly lower than those given by all other academic ranks except for doctors.

11^{th} grade mathematics topics

Differences between departments

The Figure 6 shows the differences between means of the 11^{th} grade topics for the departments. Based on that, while the largest difference exists for complex numbers and circular region in favor of electrical-electronics engineering department, matrices, counting methods, basic probability concepts, statistics - data presentation, and statistics - central tendency and dispersion in favor of computer engineering department.

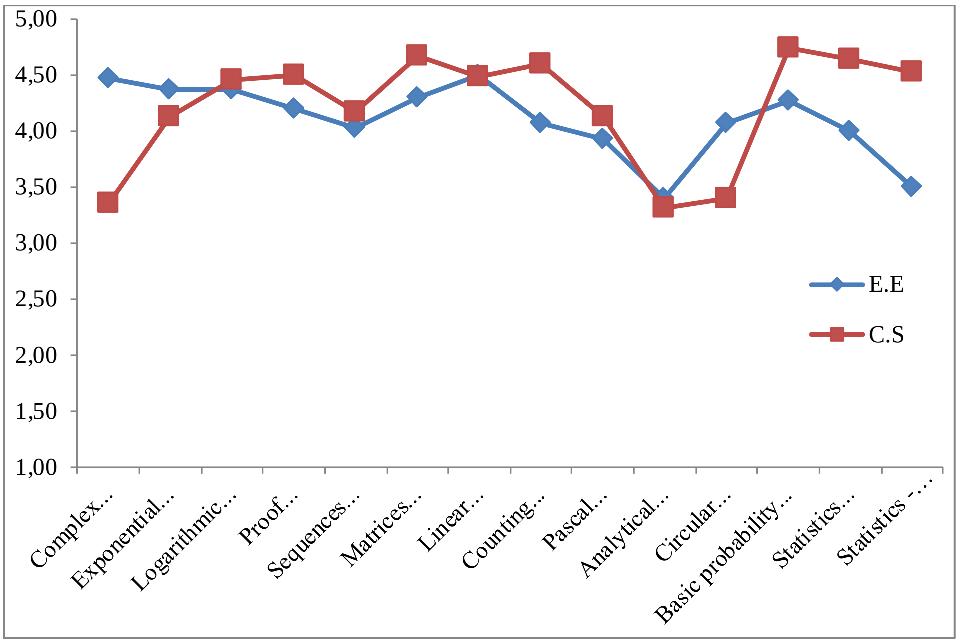


Figure 6. Means of 11^{th} grade mathematics topics for the departments

Independent samples t-test was conducted to compare mean differences in importance levels 14 topics covered in 11^{th} grade mathematics curriculum of MoNE, between two engineering departments. Results of the analysis are given in Table 11.

Table 11
Independent samples t-test results across the departments for 11th grade topics

Topics	t-test for Equality of Means			
	t	df	Sig. (2-tailed)	Mean Difference
Complex numbers	5.41	67.2	0	1.11
Exponential…	1.46	70	.15	0.25
Logarithmic…	-0.57	70	.57	-0.09
Proof…	-1.53	70	.13	-0.3
Sequences…	-0.71	70	.48	-0.13
Matrices…	-2.44	70	.02	-0.37
Linear…	0.15	70	.88	0.02
Counting…	-2.93	70	.01	-0.53
Pascal…	-0.90	70	.37	-0.19
Analytical…	0.37	70	.71	0.09
Circular…	2.84	69.99	.01	0.66
Basic probability…	-2.42	44.79	.02	-0.47
Statistics…	-2.9	44.06	.01	-0.64
Statistics – central…	-4.15	44.68	0	-1.02

As can be seen from the Table 11, for mathematics topics complex numbers, $t(67.20) = 0.00$; $p = .00$, matrices, $t(70) = 0.01$; $p = .01$, counting methods, $t(70) = 0.00$; $p = .00$, circular region, $t(69.99) = 0.01$; $p = .01$, basic probability concepts, $t(44.79) = 0.02$; $p = .02$, statistics - data presentation, $t(44.06) = 0.01$; $p = .01$, and statistics - central tendency and dispersion, $t(44.68) = 0.00$; $p = .00$ have the significant mean differences in importance between the two departments. On the other hand, exponential equations/functions, logarithmic equations/functions, natural logarithm, proof by induction, sequences, linear equation systems/applications, Pascal triangle/Binomial expansion, analytical investigation of conics have not statistically significant mean differences.

Differences between universities

Figure 7 shows the mean differences across the universities. Based on that the topic analytical investigation of conics has very low mean in both universities compared to other topics. On the other hand, a basic probability concept has the highest mean among the topics for both universities.

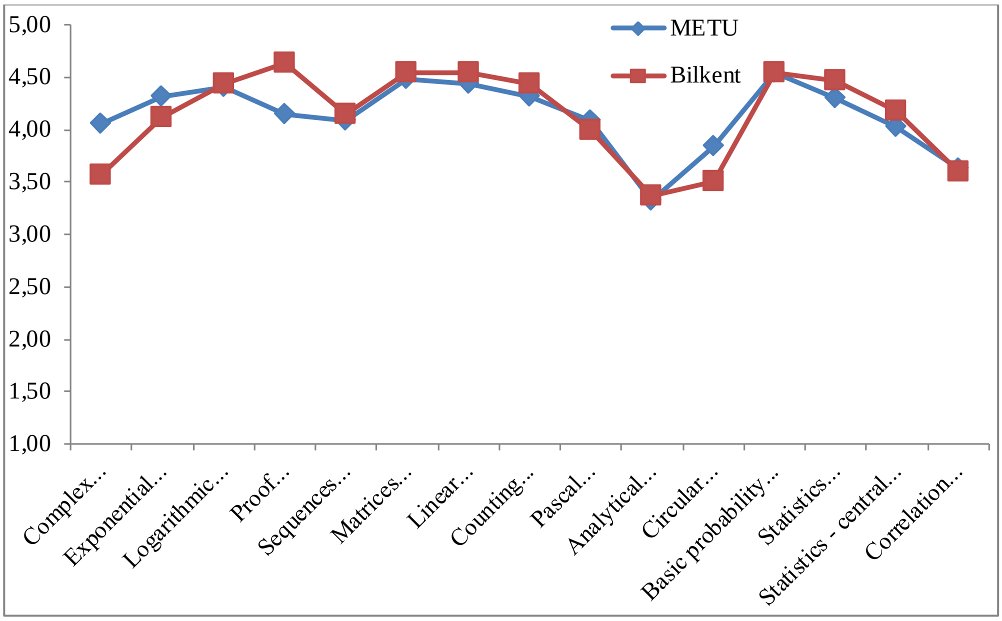


Figure 7. Means of 11th grade mathematics topics for the universities

Table 12 shows the results of t-tests conducted to investigate the mean differences among the topics across two universities.

Table 12
Independent samples t-test results across the universities for 11th grade topics

Topics	t-test for Equality of Means			
	t	df	Sig. (2-tailed)	Mean Difference
Complex numbers	1.93	70	.06	0.48
Exponential…	1.25	70	.22	0.21
Logarithmic…	-0.16	70	.88	-0.02
Proof…	-2.67	52.86	.01	-0.49
Sequences…	-0.33	70	.74	-0.06
Matrices…	-0.37	70	.72	-0.06
Linear…	-0.72	70	.48	-0.11
Counting…	-0.55	70	.58	-0.10
Pascal…	0.40	70	.69	0.08
Analytical…	-0.19	70	.85	-0.05
Circular…	1.29	70	.20	0.32
Basic probability…	-0.01	70	.99	0
Statistics…	-0.74	70	.46	-0.16
Statistics – central…	-0.57	70	.57	-0.14

As can be seen from the Table 12, for 11th grade mathematics topic, proof by induction, $t(52.86) = 0.01$; $p = .01$, has the significant mean difference in importance between the two universities. On the other hand, all other topics complex numbers, exponential, logarithmic, and so on have not statistically significant difference.

Differences among academic ranks

To investigate the differences among importance levels assigned to the 10th grade topics across academic ranks, several ANOVA were conducted. Table 13 presents the results of ANOVAs conducted and it includes all topics for which significant mean differences were found.

Table 13
ANOVA results across the academic ranks for 11th grade topics

Topics		Sum of Squares	df	Mean Square	F	Sig.
Complex numbers	Between Groups	4.32	4	1.08	0.92	.46
	Within Groups	78.33	67	1.17		
Exponential…	Between Groups	2.50	4	0.62	1.23	.31
	Within Groups	33.95	67	0.51		
Logarithmic…	Between Groups	4.64	4	1.16	3.4	.01
	Within Groups	22.86	67	0.34		
Proof…	Between Groups	0.46	4	0.12	0.16	.96
	Within Groups	48.41	67	0.72		
Sequences…	Between Groups	1.50	4	0.37	0.60	.66
	Within Groups	41.61	67	0.62		
Matrices…	Between Groups	1.99	4	0.50	1.19	.32
	Within Groups	28	67	0.42		
Linear…	Between Groups	2.01	4	0.50	1.20	.32
	Within Groups	27.98	67	0.42		
Counting…	Between Groups	3.48	4	0.87	1.41	.24
	Within Groups	41.39	67	0.62		
Pascal…	Between Groups	4.01	4	1	1.38	.25
	Within Groups	48.86	67	0.73		
Analytical…	Between Groups	6.46	4	1.62	1.59	.19
	Within Groups	67.86	67	1.01		
Circular…	Between Groups	18.86	4	4.72	5.03	0
	Within Groups	62.8	67	0.94		

Table 13 (Cont'd)
ANOVA results across the academic ranks for 11th grade topics

Basic probability…	Between Groups	1.52	4	0.38	0.60	.66
	Within Groups	42.36	67	0.63		
Statistics…	Between Groups	3.52	4	0.88	1.07	.38
	Within Groups	55.36	67	0.83		
Statistics – central…	Between Groups	2.64	4	0.66	0.55	.7
	Within Groups	79.68	67	1.19		
Correlation…	Between Groups	6.15	4	1.54	1.04	.39
	Within Groups	98.96	67	1.48		

According to the results, statistically significant mean differences were found for the topics, logarithmic equations/functions, natural logarithm, $F(4, 67) = 3.40$, $p = .01$, and circular region, $F(4, 67) = 5.03$, $p = .00$. Additional analyses including multiple comparisons among academic ranks for each topic were also conducted using LSD and Dunnett's C for equal and unequal variances, respectively. Table 14 shows the mean differences across academic in the topics for which statistical significance were found.

Table 14
Post-hoc test results for across the academic ranks 11th grade mathematics topics

Rank (i)	Rank (j)	Mean Difference (i-j) Logarithmic equations…[1]	Mean Difference (i-j) Circular region…[2]
Res. Ass.	Dr.	0.43	-0.45
	Ass. Prof.	0.15	-0.89
	Assoc. Prof	.49(*)	-1.40(*)
	Prof.	.65(*)	-1.01
Dr.	Res. Ass.	-0.43	0.45
	Ass. Prof.	-0.28	-0.44
	Assoc. Prof	0.06	-0.94
	Prof.	0.22	-0.56
Ass. Prof.	Res. Ass.	-0.15	0.89
	Dr.	0.28	0.44
	Assoc. Prof	0.34	-0.51
	Prof.	0.50(*)	-0.12
Assoc. Prof	Res. Ass.	-.49(*)	1.40(*)
	Dr.	-0.06	0.94
	Ass. Prof.	-0.34	0.51

Table 14 (Cont'd)
Post-hoc test results for across the academic ranks 11th grade mathematics topics

	Prof.	0.17	0.39
Prof.	Res. Ass.	-0.65(*)	1.01
	Dr.	-0.22	0.56
	Ass. Prof.	-0.50(*)	0.12
	Assoc. Prof	-0.17	-0.39

[1] Dunnett's C was used since assumption equality of variances did not hold.
[2] LSD was used since assumption equality of variances hold.
* indicates a significant mean difference at .05 level.

Based on the results on the Table 14, for the topic logarithmic equations significant mean difference was found among (i) research assistants and associate professors, and (ii) research assistants and professors. For the topics circular region significant mean difference were found among research assistants and associate professors. Besides, importance given by research assistants is significantly lower than those given by associate professors for the topic circular region.

12th grade mathematics topics

Differences between departments

The Figure 8 shows the differences between means of the 12th grade topics for the departments. Based on that, the topics drawing/interpreting functions graphs, derivatives, and integration have the highest mean among the topics. On the other hand, the topics limit/continuity and plane in space have low mean among the topics.

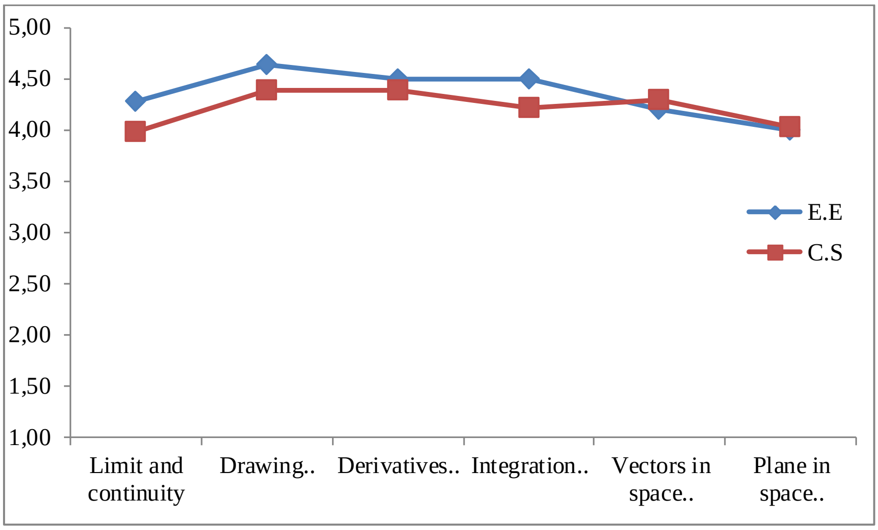


Figure 8. Means of 12th grade mathematics topics for the departments

Independent samples t-test was conducted to compare mean differences in importance levels 6 topics covered in 12th grade mathematics curriculum of MoNE, between two engineering departments. Results of the analysis are given in Table 15.

Table 15
Independent samples t-test results across the departments for 12th grade topics

Topics	t-test for Equality of Means			
	t	df	Sig. (2-tailed)	Mean Difference
Limit…	1.26	70	.21	0.29
Drawing…	1.50	70	.14	0.25
Derivatives…	0.66	70	.51	0.12
Integration…	1.47	70	.15	0.29
Vectors…	-0.39	46.96	.70	-0.09
Plane…	-0.12	70	.91	-0.02

As can be seen from the Table 15, limit/continuity, drawing/interpreting functions graph, derivatives, integration, vectors in space, plane in space have not statistically significant mean differences in importance between the two departments.

Differences between universities

Figure 9 shows the differences across the universities. The figure shows that the topic plane in space has very low mean in both universities compared to other topics. On the other hand, drawing/interpreting functions graphs has the highest mean among the topics.

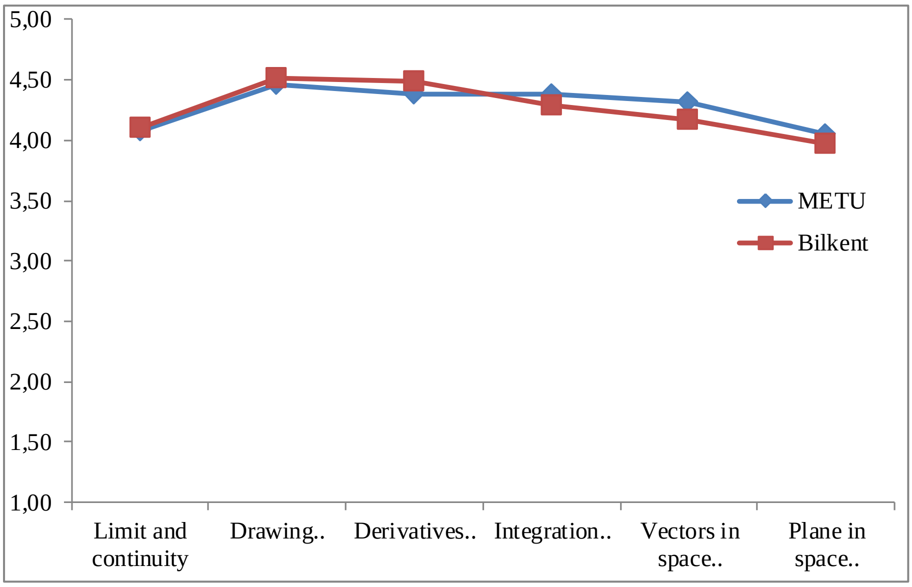


Figure 9. Means of 12th grade mathematics topics for the universities

Table 16 shows the results of t-tests conducted to check the mean differences among the topics across two universities.

Table 16
Independent samples t-test results across the universities for 12th grade topics

Topics	t-test for Equality of Means			
	t	df	Sig. (2-tailed)	Mean Difference
Limit…	-0.15	70	.89	-0.03
Drawing…	-0.33	70	.75	-0.06
Derivatives…	-0.61	70	.55	-0.11
Integration…	0.48	70	.64	0.09
Vectors…	0.75	70	.46	0.15
Plane…	0.42	70	.68	0.08

According to the results, no significant mean differences were found across the universities.

Differences among academic ranks

To investigate the differences among importance levels assigned to the 12^{th} grade topics across academic ranks, several ANOVA were conducted. The results of ANOVAs revealed that there were no significant mean differences across academic ranks.

Table 17
ANOVA results across the academic ranks for 12^{th} grade topics

Topics		Sum of Squares	df	Mean Square	F	Sig.
Limit…	Between Groups	2.66	4	0.67	0.70	.60
	Within Groups	63.66	67	0.95		
Drawing…	Between Groups	3.35	4	0.84	1.72	.16
	Within Groups	32.64	67	0.49		
Derivatives…	Between Groups	1.90	4	0.47	0.84	.50
	Within Groups	37.76	67	0.56		
Integration…	Between Groups	4.73	4	1.18	1.83	.13
	Within Groups	43.27	67	0.65		
Vectors…	Between Groups	3.37	4	0.84	1.13	.35
	Within Groups	50.13	67	0.75		
Plane…	Between Groups	5.50	4	1.37	2.12	.09
	Within Groups	43.49	67	0.65		

Based on the results on the Table 17, no significant mean differences were found across the academic ranks. Therefore, no post-hoc analyses were conducted.

International baccalaureate diploma program (IBDP) mathematics topics

Differences between departments

The Figure 10 shows the differences between means of the IBDP topics for the departments. The largest difference exists for the topics finite random variables, statistical distributions, and Bayes theorem in favor of computer engineering department. Interest/depreciation/cost has the minimum mean among the topics.

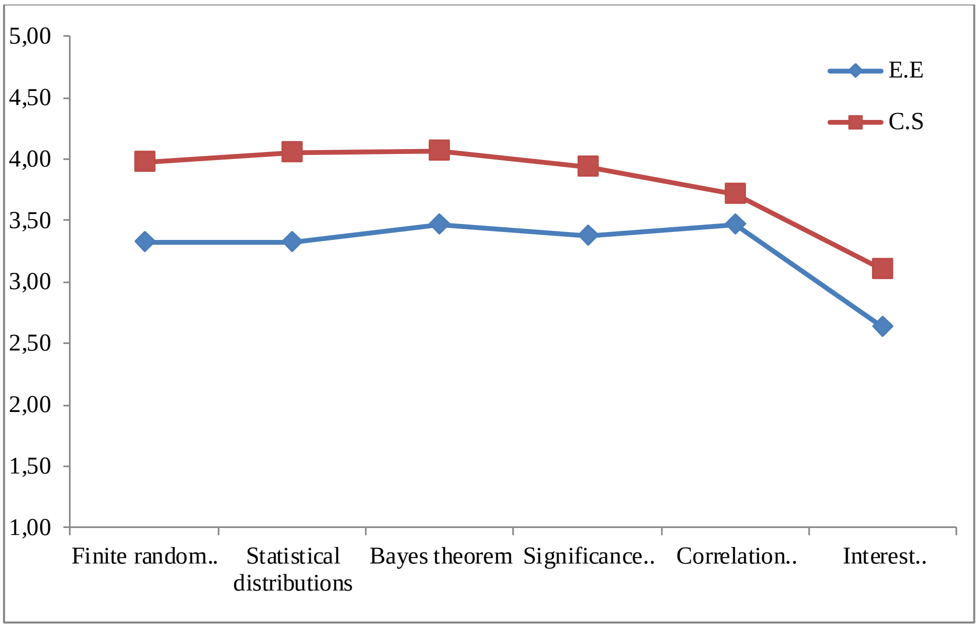


Figure 10. Means of IBDP mathematics topics for the departments

Independent samples t-test was conducted to compare mean differences in importance levels 6 topics covered in IBDP mathematics curriculum between two engineering departments. Results of the analysis are given in Table 18.

Table 18
Independent samples t-test results across the departments for IBDP topics

Topics	t-test for Equality of Means			
	t	df	Sig. (2-tailed)	Mean Difference
Finite random…	-2.73	50.74	.01	-0.64
Statistical distributions…	-2.69	70	.01	-0.71
Bayes theorem	-2.20	47.88	.03	-0.61
Significance…	-1.91	47.44	.06	-0.56
Correlation…	-0.85	70	.40	-0.25
Interest…	-1.57	51.81	.12	-0.46

Among the topics, finite random variables, statistical distributions, and Bayes theorem have been found to be statistically different. As can be seen from the Table

18, for mathematics topics finite random variables, $t(50.74) = 0.01$; $p = .01$, statistical distributions, $t(70) = 0.01$; $p = .01$, and Bayes theorem, $t(47.88) = 0.03$; $p = .03$ have the significant mean differences in importance between the two departments. On the other hand, significance/hypothesis testing, correlation/regression, and interest/depreciation/cost have not statistically significant mean differences in importance between the two departments.

Differences between universities

Figure 11 shows the differences across the universities. The figure shows that the topic interest/depreciation/cost has very low mean in both universities compared to other topics. On the other hand, Bayes theorem has the highest mean among the topics.

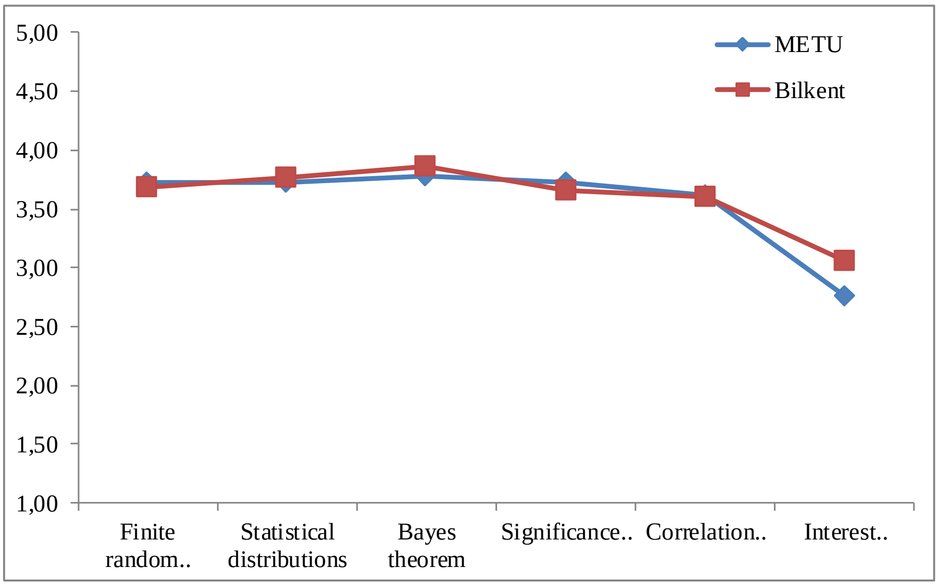


Figure 11. Means of IBDP mathematics topics for the universities

Table 19 shows the results of t-tests conducted to check the mean differences among the topics across two universities.

Table 19
Independent samples t-test results across the universities for IBDP topics

Topics	t-test for Equality of Means			
	t	df	Sig. (2-tailed)	Mean Difference
Finite random…	0.19	70	.85	0.04
Statistical distributions…	-0.15	68.25	.88	-0.04
Bayes theorem	-0.28	61.29	.78	-0.07
Significance…	0.26	64.96	.8	0.07
Correlation…	0.08	70	.94	0.02
Interest…	-1.08	67.53	.28	-0.30

According to the results, no significant mean differences were found across the universities.

Differences among academic ranks

To investigate the differences among importance levels assigned to the IBDP mathematics topics across academic ranks, several ANOVA were conducted. The results of ANOVAs revealed that there were no significant mean differences across academic ranks.

Table 20
ANOVA results across the academic ranks for IBDP topics

Topics		Sum of Squares	df	Mean Square	F	Sig.
Finite random…	Between Groups	6.84	4	1.71	1.85	.13
	Within Groups	62.04	67	0.93		
Statistical distributions…	Between Groups	5.22	4	1.31	0.97	.43
	Within Groups	90.28	67	1.35		
Bayes theorem	Between Groups	3.85	4	0.96	0.76	.56
	Within Groups	84.80	67	1.27		
Significance…	Between Groups	3.71	4	0.93	0.65	.63
	Within Groups	95.57	67	1.43		
Correlation…	Between Groups	6.15	4	1.54	1.04	.39
	Within Groups	98.96	67	1.48		
Interest…	Between Groups	9.40	4	2.35	1.73	.15
	Within Groups	90.92	67	1.36		

Based on the results on the Table 20, no significant mean differences were found across the academic ranks. Therefore, no post-hoc analyses were conducted.

Mathematical skills

Differences between departments

The Figure 12 shows the differences between means of mathematical skills for the departments. Based on that, mathematical reasoning and critical thinking have very similar means across departments. The largest difference exists for mathematical modeling, mathematical relations, mathematical representations, and analytical reasoning skills in favor of computer engineering department. Mathematical representations have the minimum mean among the skills.

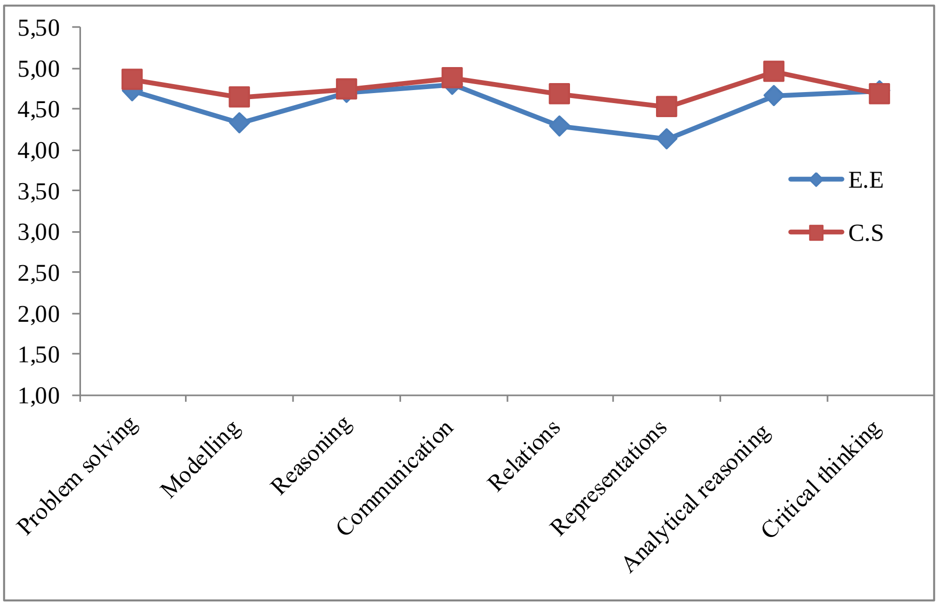


Figure 12. Means of mathematical skills for the departments

Among the mathematical skills, mathematical modeling, analytical reasoning skills, mathematical relations, and mathematical representations have been found to be statistically different. Independent samples t-test was conducted to compare mean differences in importance levels of 8 mathematical skills covered in high school mathematics curriculum of MoNE, between two engineering departments. Results of the analysis were given in Table 21.

Table 21
Independent samples t-test results across the departments for mathematical skills

Skills	t-test for Equality of Means			
	t	df	Sig. (2-tailed)	Mean Difference
Mathematical problem solving	-1.26	53.02	.22	-0.12
Mathematical modelling	-2.29	70	.03	-0.31
Mathematical reasoning	-0.33	70	.74	-0.04
Mathematical communication	-0.73	70	.47	-0.08
Mathematical relations	-3.11	70	0	-0.39
Mathematical representations	-2.50	70	.02	-0.39
Analytical reasoning skills	-2.47	34.27	.02	-0.29
Critical thinking skills	0.30	70	.76	0.04

As can be seen from the Table 21 for mathematical skills; mathematical modeling, $t(70, 00) = 0.03$, $p = .03$, mathematical relations, $t(70, 00) = 0.00$, $p = .00$, mathematical representations, $t(70, 00) = 0.02$, $p = .02$, analytical reasoning skills, $t(34, 27) = 0.02$, $p = .02$ have the significant mean differences in importance between the two departments. On the other hand, mathematical problem solving, mathematical reasoning, and critical thinking skills have not statistically significant mean differences.

Differences between universities

Figure 13 shows the differences across the universities. The figure shows that the skills, mathematical modeling and mathematical representations have very low means in both universities compared to other mathematical skills. On the other hand, analytical reasoning skill has the highest mean among the skills.

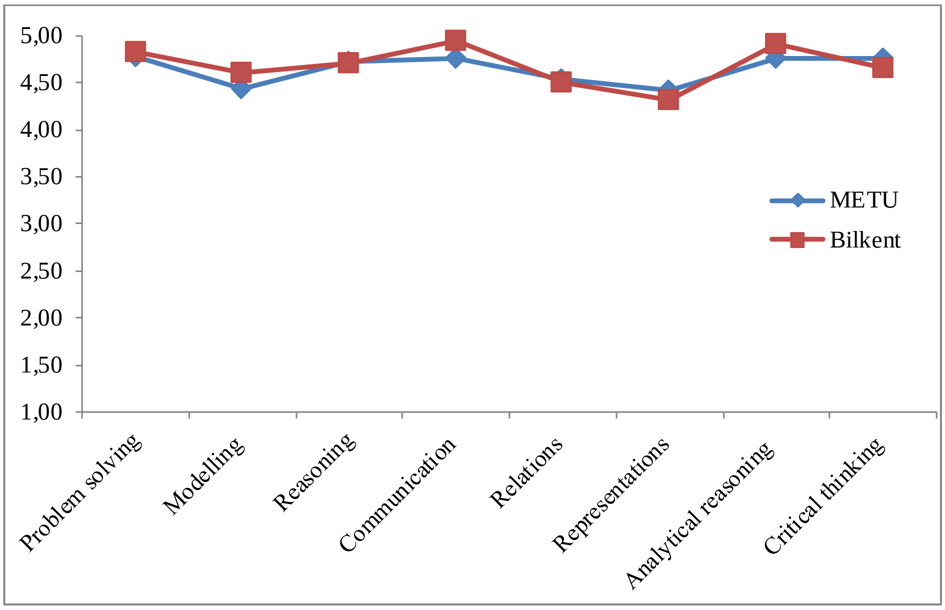


Figure 13. Means of mathematical skills for the universities

Table 22 shows the results of t-tests conducted to check the mean differences among the mathematical skills across two universities.

Table 22
Independent samples t-test results across the universities for mathematical skills

Skills	t-test for Equality of Means			
	t	df	Sig. (2-tailed)	Mean Difference
Mathematical problem solving	-0.47	70	.64	-0.05
Mathematical modelling	-1.24	67.22	.22	-0.17
Mathematical reasoning	0.14	70	.89	0.02
Mathematical communication	-1.76	47.48	.09	-0.19
Mathematical relations	0.20	70	.84	0.03
Mathematical representations	0.57	70	.57	0.09
Analytical reasoning skills	-1.54	54.68	.13	-0.16
Critical thinking skills	0.71	70	.48	0.10

According to the results, no significant mean differences were found across the universities.

Differences among academic ranks

To investigate the differences among importance levels assigned to the mathematical skills across academic ranks, several ANOVA were conducted. Table 23 presents the results of ANOVAs conducted and the results of ANOVAs showed that there were no significant mean differences across academic ranks.

Table 23
ANOVA results across the academic ranks for mathematical skills

Skills		Sum of Squares	df	Mean Square	F	Sig.
Mathematical problem solving	Between Groups	0.81	4	0.20	1.30	.28
	Within Groups	10.47	67	0.16		
Mathematical modelling	Between Groups	1.08	4	0.27	0.79	.54
	Within Groups	22.90	67	0.34		
Mathematical reasoning	Between Groups	1.13	4	0.28	1.24	.30
	Within Groups	15.31	67	0.23		
Mathematical communication	Between Groups	0.54	4	0.14	0.62	.65
	Within Groups	14.78	67	0.22		
Mathematical relations	Between Groups	1.54	4	0.38	1.26	.30
	Within Groups	20.41	67	0.31		
Mathematical representations	Between Groups	1.22	4	0.31	0.65	.63
	Within Groups	31.39	67	0.47		
Analytical reasoning skills	Between Groups	0.92	4	0.23	1.17	.33
	Within Groups	13.08	67	0.20		
Critical thinking skills	Between Groups	1.18	4	0.30	0.84	.51
	Within Groups	23.69	67	0.35		

Based on the results on the Table 23, no significant mean differences were found across the academic ranks. Therefore, no post-hoc analyses were conducted.

Summary

According to results of the analyses, there were statistically significant differences between departments in terms of the importance ascribed to some mathematics topics and mathematical skills. Almost all mathematics topics and mathematical skills were found significantly important for both computer and electrical-electronics engineering by academics. In terms of the differences between the departments, 9th and 12th grade level topics did not vary. 10th and 11th grade level topics have several differentiations between the departments. In addition, some of the IBDP topics were found to differ in importance levels between the departments. Additionally, there was no statistically significant difference between universities in terms of mathematics topics except for one topic from 11th grade. Besides, there was no statistically a difference between universities and academic ranks in terms of mathematical skills, while they differed between the departments.

CHAPTER 5: DISCUSSION

Introduction

The present study aimed to answer the following five research problems:

Based on the opinions of university staff in engineering departments, the mastery of which topics and possession of which mathematical skills are important in high school mathematics curriculum to effectively prepare students for university education in engineering fields?

To answer this question, the following five sub-questions will be investigated:

1. What are the topics of high school curricula that are needed for engineering education in university?
2. What are the mathematical skills that are needed for engineering education?
3. What are the differences between engineering departments in terms of importance levels of mathematics topics and skills given in high school?
4. What are the differences between universities with engineering departments in terms of importance levels of mathematics topics and skills given in high school?
5. What are the differences among academic staff with different ranks in engineering departments in terms of the importance levels of mathematics topics and skills given in high school?

The findings will be discussed in the following order:

1. Discussion with respect to the departments in topics
2. Discussion with respect to the universities in topics
3. Discussion with respect to academic ranks in topics
4. Differences in skills
5. Implications for practice
6. Implications for further research
7. Limitations

Discussion with respect to the departments in topics

There is a need for differentiation for departments

The 9^{th} mathematics topics, logic, mathematical proof methods, sets, and so on are considered to be of importance for the department of computer engineering which is one of the departments included in the present study. One inference from this result could be that almost all 9^{th} grade mathematics topics are considered as important to effectively prepare students for university education in computer engineering field. In addition, the 9^{th} grade mathematics topic, tessellations on the plane is not considered to be of importance.

Similarly, the same 9^{th} grade mathematics topics are considered to be of importance by participants from department of electrical-electronics engineering. For this department, the topic interest/depreciation/cost is not considered as important. The most important topic for both computer and electrical-electronics engineering is concept of function with a mean of greater than 4.50. In general almost all 9^{th} grade mathematics topics are important for computer engineering. Other inference for these results could be that almost all the 9th grade mathematics topics are important for both computer and electrical-electronics engineering. This is also supported by Güner (2008) who stated these topics as basics for these engineering fields. In addition to that, the same topic tessellation on the plane is not considered as important for both departments. Considering just one topic among all topics as not important supported that engineering department have a strong side of mathematics. This inference can be supported with the idea of engineering departments should have a strong side of mathematical structure and basic sciences (Gençoğlu & Gençoğlu, 2005, p.273) and "knowledge of mathematics is essential for the study of engineering and of most other technological subjects" (Cockcroft, 1982, p.54). Although all 9th grade topics except tessellations were found to be essential for both departments, only one *topic,* logic, was considered to be more important for computer science (CS). When the curriculum of CS departments, it seemed that logic is used in some of the courses than electrical-electronics (EE) departments do (Bilkent, 2013; METU, 2013).

The 10th grade mathematics topics, polynomials, quadratic equations/functions, trigonometric ratios, trigonometry, similarity theorems for triangles, transformations on the plane, the proof of theorems in geometry are considered to be of importance for the department of computer engineering. One inference from this result could be that almost all 10th grade mathematics topics are considered as important to effectively prepare students for university education in computer engineering field.

Nevertheless, the same 10th grade mathematics topics are considered to be of importance by participants from department of electrical-electronics engineering. The most important topic for both computer and electrical-electronics engineering is quadratic equations/functions with a mean of greater than 4.20. In general, all 10^{th} grade mathematics topics are important for both computer and electrical-electronics engineering. There were no 10^{th} grade mathematics topics, which were found as unimportant for both engineering fields. One inference from this result could be that 10^{th} grade mathematics topics can be given as a core curriculum to effectively prepare students for university education in both computer and electrical-electronics engineering fields. This analysis can be supported by the idea of Güner (2008), almost all high school mathematics topics were considered as important by electrical-electronics engineering students at the end of their education. Although all 10^{th} grade topics were found essential for both departments, only three *topics,* quadratic equations and functions, trigonometric ratios, and trigonometry were considered to be more important for electrical-electronics engineering.

The 11^{th} grade mathematics topics, complex numbers, exponential equations/functions, and so on are considered to be of importance for the department of computer engineering. One inference from this result could be that almost all 11^{th} grade mathematics topics are considered as important to effectively prepare students for university education in computer engineering field.

Additionally, the same 11^{th} grade mathematics topics are considered to be of importance by participants from department of electrical-electronics engineering. The most important topics for both computer and electrical-electronics engineering are logarithmic equations/functions, and natural logarithm/linear equation systems/applications with a mean of greater than 4.37. In general, all 11^{th} grade mathematics topics are important for both computer and electrical-electronics engineering. There were no 11^{th} grade mathematics topics which were found as unimportant for both engineering fields. One inference from this result could be that in addition to 10^{th} grade mathematics topics 11^{th} grade mathematics topics can also be given as a core curriculum to effectively prepare students for university education in both computer and electrical-electronics engineering fields. Although all 11^{th} grade topics were found essential for both departments, two *topics*, complex numbers and circular region were considered to have higher level of importance for electrical-electronics engineering. Five topics, matrices, counting methods, basic probability concepts, statistics-data presentation, and statistics-central tendency/dispersion were considered to be more important for computer engineering. In the consideration of these ideas, 11^{th} grade mathematics topics vary for departments. Other inference from these results could be that statistics topics are considered as more important to effectively prepare students for university education in computer engineering field.

The 12^{th} grade mathematics topics, limit/continuity, drawing/interpreting functions graphs, derivatives, integration, vectors in space, and plane in space are considered to be of importance for the department of computer engineering. One inference from this result could be that almost all 12^{th} grade mathematics topics are considered as important to effectively prepare students for university education in computer engineering field. In addition, the same 12^{th} grade mathematics topics are considered to be of importance by participants from department of electrical-electronics engineering. The most important topics for both computer and electrical-electronics engineering are drawing/interpreting functions graphs and derivatives with a mean of greater than 4.38. In general, all 12^{th} grade mathematics topics are important for both computer and electrical-electronics engineering. There were no 12^{th} grade mathematics topics which were found as unimportant for both engineering fields. One inference from this result could be that 12^{th} grade mathematics topics can be given as a core curriculum to effectively prepare students for university education in both computer and electrical-electronics engineering fields.

IBDP mathematics topics, finite random variables, statistical distributions, Bayes theorem, significance/hypothesis testing, correlation/regression, and interest, depreciation/cost are considered to be of importance for the department of computer engineering. One inference from this result could be that almost all IBDP mathematics topics are considered as important to effectively prepare students for university education in computer engineering field. In addition, the same IBDP mathematics topics except for interest/depreciation/cost is considered to be of importance by participants from department of electrical-electronics engineering. Although almost all IBDP topics were found essential for both departments, only three *topics*, finite random variables, statistical distributions, and Bayes theorem were considered to be more important for computer engineering.

In the light of these findings, this present showed that almost all high school mathematics topics were considered as important for both computer and electrical-electronics engineering fields to effectively prepare students for university education in these engineering fields. Besides, there is little difference among departments in terms of importance of mathematics topics. In the consideration of the research study about the students' first year mathematics performance in the engineering field, it is important that knowing students' level of high mathematics knowledge to effectively prepare students for university education in engineering field (Güner & Çomak, 2011). All these findings can be supported by the idea of direct relationship between students' success in engineering fields and the level of their mathematical knowledge coming from high school (Crowther, Thompson, & Cullingford, 1997). Moreover, according to Crawford & Schmidt (2004), the dropout rate is approximately 50% among students who have deficient mathematical knowledge from high school want to study in the fields of science and engineering in USA (as cited in Güner & Çomak, 2011).

- 9^{th} topics seemed to be equally important, except for, logic which has a higher mean score for CS.
- 10^{th} grade seemed to be equally important except for quadratic equations/functions, trigonometric ratios, and trigonometry.
- 11^{th} grade topics have different importance levels with respect to the departments.
- 12^{th} grade topics seemed to be equally important with no exception.
- IBDP topics have different importance levels with respect to the departments.
- There are few topics considered to be unimportant such as tessellations on the plane, interest/depreciation/cost.
- There are topics with higher importance levels for CS such as logic, matrices, matrices operations, determinants, counting methods, basic probability concepts, statistics-data presentation, and statistics - central tendency/dispersion, finite random variables, statistical distributions, and Bayes theorem.

In summary, results suggest that high school mathematics curriculum includes essential courses for computer science (CS) and electrical-electronics (EE) departments.

The topics given in the Table 24 shows the topics reported as important by university staff. The topics are marked by numbers *1, 2, and 3* to indicate that they have a mean difference between the departments.

Table 24
The list of important topics for both computer and electrical-electronics engineering

Grade Levels				
9th	10^{th}	11^{th}	12^{th}	IBDP
Logic...[1]	Polynomials…	Complex numbers [2]	Limit…	Finite random…[1]
Mathematical proof...	Quadratic…[2]	Exponential…	Drawing…	Statistical distributions…[1]
Sets...	Trigonometric…[2]	Logarithmic…	Derivatives…	Bayes theorem [1]
Relations...	Trigonometry…[2]	Proof…	Integration…	Significance…
Concept of function...	Synthetic geometry…	Sequences…	Vectors…	Correlation…
Modular arithmetic...	Similarity…	Matrices…[1]	Plane…	Interest….[3]
Exponential numbers...	Transformations…	Linear…		
Divisibility of integers	The proof…	Counting…[1]		
Rate/proportion		Pascal…		
Vectors...		Analytical…		
Line and circle...		Circular…[2]		
Distance...		Basic probability…[1]		
Synthetic...		Statistics…[1]		
Synthetic geometry...		Statistics – central…[1]		
Cylinder...				
Tessellations				

[1] The topic is more important for CS
[2] The topic is more important for EE
[3] The topic was considered as important only for CS

Discussion with respect to the universities in topics

Importance levels do not vary between the universities

For the topics of 9^{th}, 10^{th}, 11^{th}, and 12^{th} grade level, there are no differences between the universities in terms of grade levels. It is an expected finding that the different universities offering engineering education seem to give the similar importance to mathematics topics of high school. One inference for this argument could be that the universities have very similar curriculum. This finding can be supported by searching the universities' curriculum (Bilkent, 2013; METU, 2013). This inference can support that there is consistency between universities in terms of teaching same mathematics curriculum and academics from different universities give same importance to the topics to effectively prepare students for university education in both computer and electrical-electronics engineering. There were mean difference just for one topic proof by induction/proof methods.

Additionally, this present study showed that there were no mean differences between universities in terms of importance levels of high school mathematics topics except for one topic. One inference for this finding could be that designing a differentiated high school mathematics curriculum for specific engineering departments could be appropriate for different universities' engineering departments.

Differences with respect to academic ranks in topics

University staff with more experience does report similar importance levels

There were some mean differences among academic ranks in topics. For the 9^{th} grade mathematics topics, sets, relations, concept of function, exponential/root numbers, and divisibility of integers have mean differences between academics. In general, there were mean differences between (i) research assistants and associate professors and (ii) research assistants and professors. For the 10^{th} grade mathematics topics, similarity theorems for triangles and transformations on the plane have mean differences between academics. For these topics, the mean differences were found between (i) research assistants and associate professors, (ii) research assistants and assistant professors, and (iii) research assistants and professors. This was the similar finding with 9th grade mathematics topics and this finding revealed that research assistants who are at the beginning of their academic life give different value to the high school mathematics topics.

Similarly, the 11th grade mathematics topics, logarithmic equations, functions, circular region, and area of circular region have mean differences between academics. The mean differences were found between (i) research assistants and associate professors and (ii) research assistants and professors. There were no mean differences between academics for the 12th grade mathematics topics. This finding has parallelism with the findings of departments and universities. This addresses that 12th grade mathematics topics can be considered as a core curriculum topics for both computer and electrical-electronics engineering because comparison the mean of departments, universities, and academics showed that there were no mean differences for 12th grade mathematics topics. It is consistent with the findings of research study of freshman electrical engineering students' level of mathematics knowledge (Güner, 2008). Similarly, there were no mean differences between academics for the IBDP topics. The same interpretations can also be done for IBDP topics.

Differences in skills

Skills are important in engineering education

The mean differences for mathematics skills were investigated in terms of departments, universities, and academic ranks. The mean differences were just found for departments. The results showed that the mathematical skills which are mathematical problem solving, mathematical modeling, mathematical reasoning, mathematical communication, mathematical relations, mathematical representations, critical thinking skills, and analytical reasoning skills were considered as important for both computer and electrical-electronics engineering (Kyllonen, 2012; Bureau of Labor Statistics, 2013). One inference for this argument could be that these skills are important for students who will have a chance to choose computer and electrical-electronics engineering fields from high school. Beers's (2011), Kyllonen's (2012), Bureau of Labor Statistics's (2013) opinions have parallelism with the argument. For this reason, these skills should be integrated to the national mathematics curriculum to better prepare students who will have a chance to choose engineering fields from high school.

Implications for practice

Results suggested that packaged (differentiated) curricula designed for specific engineering departments in university can be designed for high schools. This implication can be considered with the study that was conducted in the field of social science (Özalp, 2013). As supported by the results of the present study, core topics required for both departments should be included in earlier grade levels and topics whose importance levels of which differentiated across departments are reserved for higher grades. Some topics exits in IBDP curriculum, not in MoNE, were also found to have higher importance in engineering departments except for the topic *interest/depreciation/cost*; these topics should also be considered to be added to MoNE curriculum. For the skills, there is no need to action since the topics covered in the present study are already stated in the MoNE curricula.

Implications for further research

Possible implications for further research were listed below:

- A more detailed investigation of subtopics under the topics covered in the present study could be made.
- Importance levels of engineers working the industry can also be asked to generalize the results of the present study.
- Quantitative studies can be conducted to get open-ended responses so that additional insight can be gained.
- Another curricula, such as GCSE (General Certificate of Secondary Education) followed before IBDP in many schools, can also evaluated in importance levels of its topics to gain a deeper understanding of the relationship between topics taught in the high school and engineering departments.

Limitations

The present study was conducted with academics, research assistants, and instructors in electrical-electronics and computer engineering departments in Bilkent and Middle East Technical Universities in Ankara. Besides, only importance levels reported by university staff were collected in this present study. Therefore, making generalizations was difficult with the limited sample. In addition, this present study attempted to reach a consensus only for computer and electrical-electronics engineering education in Turkey. Last, subgroups such as research assistant, Dr., and so on, in academic staff included in the present study were not check in terms of representativeness of their populations.

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APPENDICES

APPENDIX A: The questionnaire

Sayın Öğretim Elemanı;

Bu çalışmanın amacı liseden gelen öğrencilerin mühendislik bilimleri alanlarında üniversite eğitimine hazır gelmeleri ve mühendislik eğitiminde daha başarılı olmaları için sahip olmaları gereken matematiksel bilgi ve becerilerin ne olduğunu belirlemektir. Çalışmanın bulgularının matematik müfredatı planlayıcılarına yol gösterici olacağını umuyoruz. Çalışmaya katıldığınız ve zaman ayırdığınız için öncelikle teşekkür ediyoruz.

Millî Eğitim Bakanlığı (MEB) ulusal matematik müfredatında yer alan konular ve MEB müfredatında yer almayan bazı matematik konuları ve beceriler aşağıda verilmiştir. Mühendislik eğitiminde "öğrencilerimin daha başarılı olmaları için ya da daha iyi mühendis olmaları için liseden şu alanlarda daha yetkin olarak gelmelerini isterdim" diyeceğiniz konuları bu ankette belirtmenizi istiyoruz. Ankette cevaplarınızı her konu veya beceri alanı için seçeneklerden bir tanesini işaretleyerek belirtiniz.

Bazı matematiksel konular doğrudan mühendislik eğitiminde kullanılmasa da diğer matematiksel kavramlar için ön-öğrenme sağlayabilir. Bu çeşit konuları seçeneklerin altında yer alan boşluklara yorum ekleyerek belirtebilirsiniz. Burada yazılmayan ama sizin eklemeyi düşündüğünüz matematiksel konu başlığı ya da beceri varsa, lütfen onları da bölümlerin sonunda ayrılan yerlere yazınız.

Bu çalışma Bilkent Üniversitesi Eğitim Fakültesi'nden Yard. Doç. Dr. İlker Kalender gözetmenliğinde master programı öğrencisi Mehmet Başaran tarafından ortaklaşa yürütülmektedir. Bu anket yaklaşık olarak 15 dakika zamanınızı alacaktır. Size özel bilgiler gizlilikle muhafaza edilecek ve sadece çalışma ekibi tarafından kullanılacaktır.

Katılımcının:

Akademik ünvanı:
Üniversite:
Bölüm:
E-posta adresi:

A. Matematik Bilgisi

Aşağıda MEB matematik müfredatında yer alan konular ile birlikte MEB müfredatında yer almayan bazı matematik konuları bulunmaktadır. Eğer herhangi bir konunun alanınızla dolaylı olarak ilgili olduğunu düşünüyorsanız ya da yorum eklemek isterseniz "açıklama" kısmına belirtebilirsiniz.

	Hiç önemli değil	Önemli değil	Kararsızım	Önemli	Çok önemli
1. Mantık (önermeler, doğruluk tabloları, vb.)	❍	❍	❍	❍	❍
Açıklama:					
2. Matematiksel ispat yöntemleri (Tümevarım, olmayana ergi, vb.)	❍	❍	❍	❍	❍
Açıklama:					
3. Kümeler (ve kümelerde işlemler)	❍	❍	❍	❍	❍
Açıklama:					
4. Bağıntı (kümeler arası bağıntılar)	❍	❍	❍	❍	❍
Açıklama:					
5. Fonksiyon kavramı (fonksiyonların tanım ve görüntü kümesi, fonksiyonlarda işlemler)	❍	❍	❍	❍	❍
Açıklama:					
6. Modüler aritmetik (onluk tabandan farklı yazılan sayılar)	❍	❍	❍	❍	❍
Açıklama:					
7. Üslü Sayılar Köklü sayılar	❍	❍	❍	❍	❍
Açıklama:					
8. Tamsayılarda bölünebilme	❍	❍	❍	❍	❍
Açıklama:					
9. Oran / orantı	❍	❍	❍	❍	❍
Açıklama:					
10. Polinomlar (polinomlarda işlemler ve çarpanlara ayırma)	❍	❍	❍	❍	❍

Açıklama:					
11. İkinci dereceden denklemler ve fonksiyonlar	❍	❍	❍	❍	❍
Açıklama:					
12. Trigonometrik oranlar(sinüs, kosinüs, vb.)	❍	❍	❍	❍	❍
Açıklama:					
13. Trigonometri (dar açı oranları, trigonometrik fonksiyonlar, toplam ve fark formülleri, trigonometrik denklemler)	❍	❍	❍	❍	❍
Açıklama:					
14. Karmaşık sayılar	❍	❍	❍	❍	❍
Açıklama:					
15. Üstel denklemler ve fonksiyonlar	❍	❍	❍	❍	❍
Açıklama:					
16. Logaritmik denklemler ve fonksiyonlar, doğal logaritma	❍	❍	❍	❍	❍
Açıklama:					
17. Tümevarımla ispat ve ispat yöntemleri	❍	❍	❍	❍	❍
Açıklama:					
18. Diziler (aritmetik ve geometrik diziler)	❍	❍	❍	❍	❍
Açıklama:					
19. Matris, matris işlemleri ve determinantlar	❍	❍	❍	❍	❍
Açıklama:					
20. Doğrusal denklem sistemleri ve uygulamaları	❍	❍	❍	❍	❍
Açıklama:					
21. Sayma yöntemleri (permütasyon ve kombinasyon)	❍	❍	❍	❍	❍
Açıklama:					
22. Paskal üçgeni ve Binom açılımı	❍	❍	❍	❍	❍

Açıklama:					
23. Limit ve süreklilik	❍	❍	❍	❍	❍
Açıklama:					
24. Fonksiyonların grafiklerinin çizilmesi ve yorumlanması	❍	❍	❍	❍	❍
Açıklama:					
25. Türev ve türev uygulamaları	❍	❍	❍	❍	❍
Açıklama:					
26. İntegral (belirsiz integral, belirli integral, integral uygulamaları)	❍	❍	❍	❍	❍
Açıklama:					
27. Analitik düzlemde vektörler, vektör işlemleri ve uygulamaları	❍	❍	❍	❍	❍
Açıklama:					
28. Uzayda (üç boyutlu) vektörler, vektör işlemleri ve uygulamaları	❍	❍	❍	❍	❍
Açıklama:					
29. Analitik düzlemde doğrunun ve çemberin özellikleri	❍	❍	❍	❍	❍
Açıklama:					
30. Analitik düzlemde uzaklık ve uygulamaları	❍	❍	❍	❍	❍
Açıklama:					
31. Uzayda düzlem ve analitik özellikleri	❍	❍	❍	❍	❍
Açıklama:					
32. Koniklerin analitik incelemesi (parabol, hiperbol ve elips)	❍	❍	❍	❍	❍
Açıklama:					
33. Sentetik geometri: Nokta, doğru, açı, ışın, düzlem, uzay	❍	❍	❍	❍	❍
Açıklama:					
34. Sentetik geometri: Çokgenlerin ve üçgenlerin açıları ve alanları	❍	❍	❍	❍	❍

Açıklama:					
35. Üçgenlerde benzerlik teoremleri	❍	❍	❍	❍	❍
Açıklama:					
36. Daire ve daire diliminin alanı, çemberin açıları, çevre uzunluğu	❍	❍	❍	❍	❍
Açıklama:					
37. Silindir, koni, küre, prizma ve piramit ve özellikleri	❍	❍	❍	❍	❍
Açıklama:					
38. Düzlemde dönüşümler (öteleme, dönme, yansıma)	❍	❍	❍	❍	❍
Açıklama:					
39. Geometride teorem ispatları	❍	❍	❍	❍	❍
Açıklama:					
40. Düzlemde kaplama ve süslemeler (Escher süslemeleri)	❍	❍	❍	❍	❍
Açıklama:					
41. Temel olasılık kavramları (deney, çıktı, örneklem, koşullu olasılık, bağımsız ve bağımlı olaylar ve diğerleri)	❍	❍	❍	❍	❍
Açıklama:					
42. İstatistik – veri gösterimi (sütun, çizgi, kutu, serpilme, histogram vb. grafikler)	❍	❍	❍	❍	❍
Açıklama:					
43. İstatistik – merkezî eğilim ve yayılma ölçüleri	❍	❍	❍	❍	❍
Açıklama:					
44. Sonlu rasgele değişkenler	❍	❍	❍	❍	❍
Açıklama:					
45. İstatistiksel dağılımlar (binom, possion, ki-kare, ve normal dağılımlar)	❍	❍	❍	❍	❍
Açıklama:					
46. Bayes teoremi	❍	❍	❍	❍	❍
Açıklama:					

47. Anlamlılık ve hipotez testi	❍	❍	❍	❍	❍
Açıklama:					
48. Korelasyon Regresyon	❍	❍	❍	❍	❍
Açıklama:					
49. Faiz, amortisman ve maliyet hesapları	❍	❍	❍	❍	❍
Açıklama:					

Aşağıya lise matematik müfredatına eklenmesini teklif edeceğiniz konuları yazabilirsiniz.

Teklif ettiğiniz konular

	Önemli	Çok önemli
Konu 1:	❍	❍
Konu 2:	❍	❍
Konu 3:	❍	❍

B. Beceriler

Aşağıda bazı matematiksel beceriler ve kısa açıklamaları verilmiştir. Bu becerileri lise eğitimindeki deneyimlerine göre öğrenciler değişik düzeylerde geliştirebilirler. Bunlardan hangilerinin öğrencilerin üniversitedemühendislik alanındaki eğitimlerinde başarılı olmaları için önemli olduğunu seçeneklerden birini işaretleyerek belirtiniz. Boşluk bırakılan yerlere işaretlediğiniz becerinin neden bölümünüz için önemli olduğunu kısaca açıklayınız.

- **Matematiksel problem çözme** (matematiksel kavram ve kuralların sıradan olmayan *problemlerin çözümünde* etkin olarak kullanılabilmesi)

Hiç önemli değil	Önemli değil	Kararsızım	Önemli	Çok önemli
❍	❍	❍	❍	❍

- **Matematiksel modelleme** (matematiksel dil ve kavramları kullanarak, fen, sosyal bilimler, mühendislik, iktisat vb. alanlardan problem durumlarını açıklayan ve öngören *modeller kurulabilmesi*)

Hiç önemli değil	Önemli değil	Kararsızım	Önemli	Çok önemli
❍	❍	❍	❍	❍

- **Matematiksel fikir yürütme** (matematiksel kural, genelleme ve çözümlerin arkasındaki *'neden'lerin anlaşılması*, formül ezberinin ötesine geçilmesi)

Hiç önemli değil	Önemli değil	Kararsızım	Önemli	Çok önemli
❍	❍	❍	❍	❍

- **Matematiksel iletişim (***matematiksel düşüncelerin* standart matematiksel terim ve sembollerle diğer insanların anlayabileceği şekilde *anlatılabilmesi*)

Hiç önemli değil	Önemli değil	Kararsızım	Önemli	Çok önemli
❍	❍	❍	❍	❍

- **Matematiksel bağlantılar** (matematiksel kavramlar, matematikle diğer fen alanları ve matematikle günlük hayat arasında bağlantılar kurulabilmesi)

Hiç önemli değil	Önemli değil	Kararsızım	Önemli	Çok önemli
❍	❍	❍	❍	❍

- **Matematiksel çoklu gösterimler** (bir kavramın, -örneğin fonksiyon- cebir, grafik, tablo, diyagram vb. yöntemlerle çoklu gösterimi ve aradaki geçişlerin ve ilişkilerin kurulabilmesi)

Hiç önemli değil	Önemli değil	Kararsızım	Önemli	Çok önemli
❍	❍	❍	❍	❍

- **Analitik düşünme becerisi** (Bir bütünün işleyişini anlamak için parçalar ve parçalar arasındaki ilişkilerin soyut olarak ayrıştırılabilmesi)

Hiç önemli değil	Önemli değil	Kararsızım	Önemli	Çok önemli
❍	❍	❍	❍	❍

- **Eleştirel düşünme becerisi** (Bir şeyin –argüman, söylem, haber, veya araştırma- geçerliliğini değerlendirmek için sistemli olarak fikir yürütebilme)

Hiç önemli değil	Önemli değil	Kararsızım	Önemli	Çok önemli
❍	❍	❍	❍	❍

Önemli gördüğünüz diğer beceriler

1. ________________

2. ________________

3. ________________

Görüşlerinizi daha detaylı olarak kişisel bir mülakatla paylaşmak ister misiniz? Size bu konuda ulaşabilir miyiz?

- ❍ Evet
- ❍ Hayır

Iletişim bilgileriniz

Adınız ve Soyadınız:

Telefon numaranız:

Sizi ne zaman arayabiliriz?

APPENDIX B: 9th grade results for departments

	Department	N	Mean	Std. Deviation	Std. Error Mean
Logic (truth tables, propositions etc.)	E.E	30	4,27	0,944	0,172
	C.S	42	4,79	0,415	0,064
Mathematical proof methods (Induction, proof by contradiction, etc.)	E.E	30	4,27	0,907	0,166
	C.S	42	4,64	0,485	0,075
Sets (and operations with sets)	E.E	30	4,23	0,679	0,124
	C.S	42	4,4	0,857	0,132
Relations (relations between sets)	E.E	30	4,23	0,504	0,092
	C.S	42	4,36	0,759	0,117
Concept of function (domain and range sets of functions, operations on functions)	E.E	30	4,73	0,45	0,082
	C.S	42	4,74	0,497	0,077
Modular arithmetic (the numbers that are not in 10 base)	E.E	30	4,27	0,828	0,151
	C.S	42	4,55	0,772	0,119
Exponential numbers and root numbers	E.E	30	4,5	0,731	0,133
	C.S	42	4,26	0,939	0,145
Divisibility of integers	E.E	30	4,13	0,776	0,142
	C.S	42	4,24	0,79	0,122
Rate/proportion	E.E	30	4,47	0,9	0,164
	C.S	42	4,29	0,944	0,146
Vectors in analytic plane, operations and vectors	E.E	30	4,43	0,774	0,141
	C.S	42	4,45	0,593	0,091
Line and circle properties in the analytic plane	E.E	30	3,87	1,008	0,184
	C.S	42	3,98	0,841	0,13
Distance and applications in analytic plane	E.E	30	4,07	0,944	0,172
	C.S	42	4,14	0,783	0,121
Synthetic geometry: point, line, angle, ray, plane, space	E.E	30	3,47	1,042	0,19
	C.S	42	3,62	1,168	0,18
Synthetic geometry: angles and areas of triangles and polygons	E.E	30	3,7	0,952	0,174
	C.S	42	3,5	1,174	0,181
Cylinder, cone, sphere, prism, pyramid and their properties	E.E	30	3,57	0,774	0,141
	C.S	42	3,26	1,191	0,184
Tesselations on the plane (Escher's drawings)	E.E	30	2,73	0,74	0,135
	C.S	42	2,74	0,912	0,141

APPENDIX C: 9th grade results for universities

	Institution	N	Mean	Std. Deviation	Std. Error Mean
Logic (truth tables, propositions etc.)	METU	37	4,43	0,899	0,148
	Bilkent	35	4,71	0,458	0,077
Mathematical proof methods (Induction, proof by contradiction, etc.)	METU	37	4,41	0,865	0,142
	Bilkent	35	4,57	0,502	0,085
Sets (and operations with sets)	METU	37	4,3	0,777	0,128
	Bilkent	35	4,37	0,808	0,136
Relations (relations between sets)	METU	37	4,3	0,571	0,094
	Bilkent	35	4,31	0,758	0,128
Concept of function (domain and range sets of functions, operations on functions)	METU	37	4,73	0,45	0,074
	Bilkent	35	4,74	0,505	0,085
Modular arithmetic (the numbers that are not in 10 base)	METU	37	4,35	0,889	0,146
	Bilkent	35	4,51	0,702	0,119
Exponential numbers and root numbers	METU	37	4,3	0,968	0,159
	Bilkent	35	4,43	0,739	0,125
Divisibility of integers	METU	37	4,16	0,727	0,12
	Bilkent	35	4,23	0,843	0,143
Rate/proportion	METU	37	4,43	0,899	0,148
	Bilkent	35	4,29	0,957	0,162
Vectors in analytic plane, operations and vectors	METU	37	4,49	0,692	0,114
	Bilkent	35	4,4	0,651	0,11
Line and circle properties in the analytic plane	METU	37	3,92	0,862	0,142
	Bilkent	35	3,94	0,968	0,164
Distance and applications in analytic plane	METU	37	4,08	0,862	0,142
	Bilkent	35	4,14	0,845	0,143
Synthetic geometry: point, line, angle, ray, plane, space	METU	37	3,49	0,989	0,163
	Bilkent	35	3,63	1,239	0,209
Synthetic geometry: angles and areas of triangles and polygons	METU	37	3,68	1,029	0,169
	Bilkent	35	3,49	1,147	0,194
Cylinder, cone, sphere, prism, pyramid and their properties	METU	37	3,51	0,932	0,153
	Bilkent	35	3,26	1,146	0,194
Tessellations on the plane (Escher's drawings)	METU	37	2,81	0,908	0,149
	Bilkent	35	2,66	0,765	0,129

APPENDIX D: 9th grade results for academic ranks

	Academic ranks	N	Mean	Std. Deviation	Std. Error
Logic (truth tables, propositions etc.)	Research assistant	17	4,41	0,795	0,193
	Dr	6	4,67	0,816	0,333
	Ass. Prof.	13	4,23	1,092	0,303
	Assoc. Prof	18	4,78	0,428	0,101
	Prof.	18	4,72	0,461	0,109
	Total	72	4,57	0,728	0,086
Mathematical proof methods (Induction, proof by contradiction, etc.)	Research assistant	17	4,24	0,752	0,182
	Dr	6	4,5	0,548	0,224
	Ass. Prof.	13	4,38	1,121	0,311
	Assoc. Prof	18	4,67	0,485	0,114
	Prof.	18	4,61	0,502	0,118
	Total	72	4,49	0,712	0,084
Sets (and operations with sets)	Research assistant	17	3,59	1,004	0,243
	Dr	6	4,33	0,516	0,211
	Ass. Prof.	13	4,46	0,519	0,144
	Assoc. Prof	18	4,67	0,485	0,114
	Prof.	18	4,61	0,608	0,143
	Total	72	4,33	0,787	0,093
Relations (relations between sets)	Research assistant	17	3,88	0,857	0,208
	Dr	6	4,17	0,408	0,167
	Ass. Prof.	13	4,46	0,519	0,144
	Assoc. Prof	18	4,39	0,502	0,118
	Prof.	18	4,56	0,616	0,145
	Total	72	4,31	0,664	0,078
Concept of function (domain and range sets of functions, operations on functions)	Research assistant	17	4,41	0,618	0,15
	Dr	6	4,67	0,516	0,211
	Ass. Prof.	13	4,69	0,48	0,133
	Assoc. Prof	18	5	0	0
	Prof.	18	4,83	0,383	0,09
	Total	72	4,74	0,475	0,056
Modular arithmetic (the numbers that are not in 10 base)	Research assistant	17	4,12	1,166	0,283
	Dr	6	4,33	0,816	0,333
	Ass. Prof.	13	4,62	0,506	0,14
	Assoc. Prof	18	4,67	0,485	0,114
	Prof.	18	4,39	0,778	0,183
	Total	72	4,43	0,802	0,095

APPENDIX D (cont'd): 9th grade results for academic ranks

Exponential numbers and root numbers	Research assistant	17	3,94	1,144	0,277
	Dr	6	3,67	0,516	0,211
	Ass. Prof.	13	4,77	0,439	0,122
	Assoc. Prof	18	4,78	0,548	0,129
	Prof.	18	4,28	0,826	0,195
	Total	72	4,36	0,861	0,101
Divisibility of integers	Research assistant	17	3,94	0,899	0,218
	Dr	6	3,83	0,408	0,167
	Ass. Prof.	13	4,62	0,506	0,14
	Assoc. Prof	18	4,44	0,705	0,166
	Prof.	18	4	0,84	0,198
	Total	72	4,19	0,781	0,092
Rate/proportion	Research assistant	17	3,88	1,364	0,331
	Dr	6	3,5	0,837	0,342
	Ass. Prof.	13	4,77	0,439	0,122
	Assoc. Prof	18	4,83	0,383	0,09
	Prof.	18	4,33	0,686	0,162
	Total	72	4,36	0,924	0,109
Vectors in analytic plane, operations and vectors	Research assistant	17	4,47	0,717	0,174
	Dr	6	4,33	0,516	0,211
	Ass. Prof.	13	4,77	0,439	0,122
	Assoc. Prof	18	4,33	0,84	0,198
	Prof.	18	4,33	0,594	0,14
	Total	72	4,44	0,669	0,079
Line and circle properties in the analytic plane	Research assistant	17	3,47	1,125	0,273
	Dr	6	4	1,095	0,447
	Ass. Prof.	13	4,23	0,439	0,122
	Assoc. Prof	18	3,94	0,873	0,206
	Prof.	18	4,11	0,832	0,196
	Total	72	3,93	0,909	0,107
Distance and applications in analytic plane	Research assistant	17	3,71	1,105	0,268
	Dr	6	4	0,632	0,258
	Ass. Prof.	13	4,31	0,48	0,133
	Assoc. Prof	18	4,22	0,878	0,207
	Prof.	18	4,28	0,752	0,177
	Total	72	4,11	0,848	0,1

APPENDIX D (cont'd): 9th grade results for academic ranks

Synthetic geometry: point, line, angle, ray, plane, space	Research assistant	17	3	1,414	0,343
	Dr	6	3,17	0,753	0,307
	Ass. Prof.	13	4,08	0,76	0,211
	Assoc. Prof	18	3,67	1,029	0,243
	Prof.	18	3,72	1,018	0,24
	Total	72	3,56	1,112	0,131
Synthetic geometry: angles and areas of triangles and polygons	Research assistant	17	3,29	1,572	0,381
	Dr	6	3,17	0,753	0,307
	Ass. Prof.	13	3,92	0,862	0,239
	Assoc. Prof	18	3,72	0,826	0,195
	Prof.	18	3,61	0,979	0,231
	Total	72	3,58	1,084	0,128
Cylinder, cone, sphere, prism, pyramid and their properties	Research assistant	17	2,82	1,185	0,287
	Dr	6	3	1,265	0,516
	Ass. Prof.	13	3,54	0,877	0,243
	Assoc. Prof	18	3,72	0,958	0,226
	Prof.	18	3,61	0,85	0,2
	Total	72	3,39	1,042	0,123
Tessellations on the plane (Escher's drawings)	Research assistant	17	2,65	0,931	0,226
	Dr	6	2,83	0,753	0,307
	Ass. Prof.	13	2,85	0,801	0,222
	Assoc. Prof	18	2,67	0,767	0,181
	Prof.	18	2,78	0,943	0,222
	Total	72	2,74	0,839	0,099

APPENDIX E: 10th grade results for departments

	Department	N	Mean	Std. Deviation	Std. Error Mean
Polinomials (operations on polynomials and factorization)	E.E	30	4,5	0,572	0,104
	C.S	42	4,19	0,833	0,129
Quadratic equations and functions	E.E	30	4,67	0,547	0,1
	C.S	42	4,26	0,798	0,123
Trigonometric ratios (sine, cosine, etc.)	E.E	30	4,67	0,547	0,1
	C.S	42	4	0,937	0,145
Trigonometry (acute angle ratios, trigonometric functions, compound angle formula, trigonometric equations)	E.E	30	4,47	0,681	0,124
	C.S	42	3,93	0,997	0,154
Similarity theorems for triangles	E.E	30	3,5	1,009	0,184
	C.S	42	3,36	1,122	0,173
Transformations on the plane (translation, revolution, reflection)	E.E	30	3,63	1,033	0,189
	C.S	42	3,55	1,173	0,181
The proof of theorems in geometry	E.E	30	3,47	1,167	0,213
	C.S	42	3,45	0,993	0,153

APPENDIX F: 10th grade results for universities

	Institution	N	Mean	Std. Deviation	Std. Error Mean
Polynomials (operations on polynomials and factorization)	METU	37	4,35	0,633	0,104
	Bilkent	35	4,29	0,86	0,145
Quadratic equations and functions	METU	37	4,54	0,73	0,12
	Bilkent	35	4,31	0,718	0,121
Trigonometric ratios (sine, cosine, etc.)	METU	37	4,41	0,762	0,125
	Bilkent	35	4,14	0,944	0,16
Trigonometry (acute angle ratios, trigonometric functions, compound angle formula, trigonometric equations)	METU	37	4,35	0,716	0,118
	Bilkent	35	3,94	1,056	0,178
Similarity theorems for triangles	METU	37	3,49	1,121	0,184
	Bilkent	35	3,34	1,027	0,174
Transformations on the plane (translation, revolution, reflection)	METU	37	3,7	1,102	0,181
	Bilkent	35	3,46	1,12	0,189
The proof of theorems in geometry	METU	37	3,38	1,139	0,187
	Bilkent	35	3,54	0,98	0,166

APPENDIX G: 10th grade results for academic ranks

	Academic ranks	N	Mean	Std. Deviation	Std. Error
Polynomials (operations on polynomials and factorization)	Research assistant	17	4,18	1,015	0,246
	Dr	6	4	0,632	0,258
	Ass. Prof.	13	4,54	0,519	0,144
	Assoc. Prof	18	4,44	0,784	0,185
	Prof.	18	4,28	0,575	0,135
	Total	72	4,32	0,747	0,088
Quadratic equations and functions	Research assistant	17	4,35	0,862	0,209
	Dr	6	4,17	0,408	0,167
	Ass. Prof.	13	4,62	0,65	0,18
	Assoc. Prof	18	4,61	0,698	0,164
	Prof.	18	4,28	0,752	0,177
	Total	72	4,43	0,728	0,086
Trigonometric ratios (sine, cosine, etc.)	Research assistant	17	4,06	1,088	0,264
	Dr	6	4	0,632	0,258
	Ass. Prof.	13	4,38	0,65	0,18
	Assoc. Prof	18	4,28	1,018	0,24
	Prof.	18	4,5	0,618	0,146
	Total	72	4,28	0,859	0,101
Trigonometry (acute angle ratios, trigonometric functions, compound angle formula, trigonometric equations)	Research assistant	17	4,12	1,111	0,27
	Dr	6	3,5	0,837	0,342
	Ass. Prof.	13	4,38	0,65	0,18
	Assoc. Prof	18	4,22	1,06	0,25
	Prof.	18	4,17	0,707	0,167
	Total	72	4,15	0,914	0,108
Similarity theorems for triangles	Research assistant	17	2,88	1,269	0,308
	Dr	6	2,67	0,816	0,333
	Ass. Prof.	13	3,77	0,725	0,201
	Assoc. Prof	18	3,67	1,085	0,256
	Prof.	18	3,67	0,907	0,214
	Total	72	3,42	1,071	0,126
Transformations on the plane (translation, revolution, reflection)	Research assistant	17	2,88	1,409	0,342
	Dr	6	2,83	0,983	0,401
	Ass. Prof.	13	4	0,913	0,253
	Assoc. Prof	18	4	0,84	0,198
	Prof.	18	3,78	0,808	0,191
	Total	72	3,58	1,11	0,131

APPENDIX G (cont'd): 10th grade results for academic ranks

The proof of theorems in geometry	Research assistant	17	3,06	1,144	0,277
	Dr	6	3,17	0,753	0,307
	Ass. Prof.	13	3,31	1,251	0,347
	Assoc. Prof	18	3,83	1,043	0,246
	Prof.	18	3,67	0,84	0,198
	Total	72	3,46	1,061	0,125

APPENDIX H: 11th grade results for departments

	Department	N	Mean	Std. Deviation	Std. Error Mean
Complex numbers	E.E	30	4,47	0,629	0,115
	C.S	42	3,36	1,1	0,17
Exponential equations and functions	E.E	30	4,37	0,669	0,122
	C.S	42	4,12	0,739	0,114
Logarithmic equations and functions, natural logarithm	E.E	30	4,37	0,669	0,122
	C.S	42	4,45	0,593	0,091
Proof by induction and proof methods	E.E	30	4,2	1,031	0,188
	C.S	42	4,5	0,634	0,098
Sequences (arithmetic and geometric sequences)	E.E	30	4,03	0,765	0,14
	C.S	42	4,17	0,794	0,122
Matrices, matrices operations and determinants	E.E	30	4,3	0,75	0,137
	C.S	42	4,67	0,526	0,081
Linear equation systems and applications	E.E	30	4,5	0,572	0,104
	C.S	42	4,48	0,707	0,109
Counting methods (permutation and combination)	E.E	30	4,07	0,785	0,143
	C.S	42	4,6	0,734	0,113
Pascal triangle and Binomial expansion	E.E	30	3,93	0,785	0,143
	C.S	42	4,12	0,916	0,141
Analytical investigation of conics (parabola, hyperbola and ellipse)	E.E	30	3,4	0,932	0,17
	C.S	42	3,31	1,093	0,169
Circular region and area of circular region, the angles of a circle , circumference of a circle	E.E	30	4,07	0,828	0,151
	C.S	42	3,4	1,149	0,177
Basic probability concepts (experiment, output, sample, conditional probability, independent and dependent events and others)	E.E	30	4,27	0,944	0,172
	C.S	42	4,74	0,587	0,091
Statistics - Data presentation (graphs such as column, line, box, scatter, histogram etc. graphs)	E.E	30	4	1,083	0,198
	C.S	42	4,64	0,656	0,101
Statistics - central tendency and dispersion	E.E	30	3,5	1,196	0,218
	C.S	42	4,52	0,74	0,114

APPENDIX I: 11th grade results for universities

	Institutiton	N	Mean	Std. Deviation	Std. Error Mean
Complex numbers	METU	37	4,05	1,026	0,169
	Bilkent	35	3,57	1,092	0,185
Exponential equations and functions	METU	37	4,32	0,669	0,11
	Bilkent	35	4,11	0,758	0,128
Logarithmic equations and functions, natural logarithm	METU	37	4,41	0,599	0,098
	Bilkent	35	4,43	0,655	0,111
Proof by induction and proof methods	METU	37	4,14	1,004	0,165
	Bilkent	35	4,63	0,49	0,083
Sequences (arithmetic and geometric sequences)	METU	37	4,08	0,829	0,136
	Bilkent	35	4,14	0,733	0,124
Matrices, matrices operations and determinants	METU	37	4,49	0,559	0,092
	Bilkent	35	4,54	0,741	0,125
Linear equation systems and applications	METU	37	4,43	0,689	0,113
	Bilkent	35	4,54	0,611	0,103
Counting methods (permutation and combination)	METU	37	4,32	0,747	0,123
	Bilkent	35	4,43	0,85	0,144
Pascal triangle and Binomial expansion	METU	37	4,08	0,722	0,119
	Bilkent	35	4	1	0,169
Analytical investigation of conics (parabola, hyperbola and ellipse)	METU	37	3,32	1,029	0,169
	Bilkent	35	3,37	1,031	0,174
Circular region and area of circular region, the angles of a circle, circumference of a circle	METU	37	3,84	0,958	0,157
	Bilkent	35	3,51	1,173	0,198
Basic probability concepts (experiment, output, sample, conditional probability, independent and dependent events and others)	METU	37	4,54	0,836	0,138
	Bilkent	35	4,54	0,741	0,125
Statistics - Data presentation (graphs such as column, line, box, scatter, histogram etc. graphs)	METU	37	4,3	0,996	0,164
	Bilkent	35	4,46	0,817	0,138
Statistics - central tendency and dispersion	METU	37	4,03	1,19	0,196
	Bilkent	35	4,17	0,954	0,161

APPENDIX J: 11th grade results for academic ranks

	Academic ranks	N	Mean	Std. Deviation	Std. Error
Complex numbers	Research assistant	17	3,71	1,16	0,281
	Dr	6	3,17	0,753	0,307
	Ass. Prof.	13	3,85	0,987	0,274
	Assoc. Prof	18	4,11	1,079	0,254
	Prof.	18	3,83	1,15	0,271
	Total	72	3,82	1,079	0,127
Exponential equations and functions	Research assistant	17	4,06	0,827	0,201
	Dr	6	4,17	0,753	0,307
	Ass. Prof.	13	4,54	0,519	0,144
	Assoc. Prof	18	4,33	0,686	0,162
	Prof.	18	4,06	0,725	0,171
	Total	72	4,22	0,716	0,084
Logarithmic equations and functions, natural logarithm	Research assistant	17	4,76	0,437	0,106
	Dr	6	4,33	0,516	0,211
	Ass. Prof.	13	4,62	0,506	0,14
	Assoc. Prof	18	4,28	0,669	0,158
	Prof.	18	4,11	0,676	0,159
	Total	72	4,42	0,622	0,073
Proof by induction and proof methods	Research assistant	17	4,35	1,057	0,256
	Dr	6	4,33	0,816	0,333
	Ass. Prof.	13	4,23	1,166	0,323
	Assoc. Prof	18	4,44	0,511	0,121
	Prof.	18	4,44	0,616	0,145
	Total	72	4,38	0,83	0,098
Sequences (arithmetic and geometric sequences)	Research assistant	17	4,24	0,903	0,219
	Dr	6	4	1,095	0,447
	Ass. Prof.	13	4	0,577	0,16
	Assoc. Prof	18	3,94	0,802	0,189
	Prof.	18	4,28	0,669	0,158
	Total	72	4,11	0,779	0,092
Matrices, matrices operations and determinants	Research assistant	17	4,71	0,588	0,143
	Dr	6	4,67	0,516	0,211
	Ass. Prof.	13	4,62	0,65	0,18
	Assoc. Prof	18	4,44	0,616	0,145
	Prof.	18	4,28	0,752	0,177
	Total	72	4,51	0,65	0,077

APPENDIX J (cont'd): 11th grade results for academic ranks

Linear equation systems and applications	Research assistant	17	4,41	0,87	0,211
	Dr	6	4,5	0,548	0,224
	Ass. Prof.	13	4,77	0,439	0,122
	Assoc. Prof	18	4,56	0,616	0,145
	Prof.	18	4,28	0,575	0,135
	Total	72	4,49	0,65	0,077
Counting methods (permutation and combination)	Research assistant	17	4,06	1,088	0,264
	Dr	6	4,67	0,516	0,211
	Ass. Prof.	13	4,46	0,519	0,144
	Assoc. Prof	18	4,61	0,608	0,143
	Prof.	18	4,28	0,826	0,195
	Total	72	4,38	0,795	0,094
Pascal triangle and Binomial expansion	Research assistant	17	3,71	1,047	0,254
	Dr	6	4,33	0,516	0,211
	Ass. Prof.	13	4	0,707	0,196
	Assoc. Prof	18	4,33	0,594	0,14
	Prof.	18	4	1,029	0,243
	Total	72	4,04	0,863	0,102
Analytical investigation of conics (parabola, hyperbola and ellipse)	Research assistant	17	2,94	1,249	0,303
	Dr	6	3,5	1,049	0,428
	Ass. Prof.	13	3,23	0,832	0,231
	Assoc. Prof	18	3,33	0,97	0,229
	Prof.	18	3,78	0,878	0,207
	Total	72	3,35	1,023	0,121
Circular region and area of circular region, the angles of a circle, circumference of a circle	Research assistant	17	2,88	1,219	0,296
	Dr	6	3,33	1,211	0,494
	Ass. Prof.	13	3,77	0,927	0,257
	Assoc. Prof	18	4,28	0,669	0,158
	Prof.	18	3,89	0,9	0,212
	Total	72	3,68	1,072	0,126
Basic probability concepts (experiment, output, sample, conditional probability, independent and dependent events and others)	Research assistant	17	4,53	0,624	0,151
	Dr	6	4,17	1,329	0,543
	Ass. Prof.	13	4,46	1,127	0,312
	Assoc. Prof	18	4,72	0,575	0,135
	Prof.	18	4,56	0,616	0,145
	Total	72	4,54	0,786	0,093

APPENDIX J (cont'd): 11th grade results for academic ranks

Statistics - Data presentation (graphs such as column, line, box, scatter, histogram etc. graphs)	Research assistant	17	4	1,225	0,297
	Dr	6	4,5	0,548	0,224
	Ass. Prof.	13	4,62	0,65	0,18
	Assoc. Prof	18	4,39	0,916	0,216
	Prof.	18	4,5	0,786	0,185
	Total	72	4,38	0,911	0,107
Statistics - central tendency and dispersion	Research assistant	17	3,82	1,286	0,312
	Dr	6	4,17	1,169	0,477
	Ass. Prof.	13	4,31	0,751	0,208
	Assoc. Prof	18	4	1,237	0,291
	Prof.	18	4,28	0,895	0,211
	Total	72	4,1	1,077	0,127

APPENDIX K: 12th grade results for departments

	Department	N	Mean	Std. Deviation	Std. Error Mean
Limit and continuity	E.E	30	4,27	0,944	0,172
	C.S	42	3,98	0,975	0,15
Drawing and interpretting functions graphs	E.E	30	4,63	0,556	0,102
	C.S	42	4,38	0,795	0,123
Derivatives and their application	E.E	30	4,5	0,861	0,157
	C.S	42	4,38	0,661	0,102
Integration (Indefinite integrals, definite integrals, application of integrals)	E.E	30	4,5	0,82	0,15
	C.S	42	4,21	0,813	0,125
Vectors in space (three dimensional), operations and vectors	E.E	30	4,2	1,064	0,194
	C.S	42	4,29	0,708	0,109
Plane in space and analytic properties	E.E	30	4	0,788	0,144
	C.S	42	4,02	0,869	0,134

APPENDIX L: 12th grade results for universities

	Institution	N	Mean	Std. Deviation	Std. Error Mean
Limit and continuity	METU	37	4,08	1,09	0,179
	Bilkent	35	4,11	0,832	0,141
Drawing and interpreting functions graphs	METU	37	4,46	0,803	0,132
	Bilkent	35	4,51	0,612	0,103
Derivatives and their application	METU	37	4,38	0,828	0,136
	Bilkent	35	4,49	0,658	0,111
Integration (Indefinite integrals, definite integrals, application of integrals)	METU	37	4,38	0,924	0,152
	Bilkent	35	4,29	0,71	0,12
Vectors in space (three dimensional), operations and vectors	METU	37	4,32	0,944	0,155
	Bilkent	35	4,17	0,785	0,133
Plane in space and analytic properties	METU	37	4,05	0,743	0,122
	Bilkent	35	3,97	0,923	0,156

APPENDIX M: 12th grade results for academic ranks

	Academic ranks	N	Mean	Std. Deviation	Std. Error
Limit and continuity	Research assistant	17	3,76	1,033	0,25
	Dr	6	4,17	0,408	0,167
	Ass. Prof.	13	4,31	1,182	0,328
	Assoc. Prof	18	4,17	0,786	0,185
	Prof.	18	4,17	1,043	0,246
	Total	72	4,1	0,966	0,114
Drawing and interpreting functions graphs	Research assistant	17	4,24	0,97	0,235
	Dr	6	4,33	0,516	0,211
	Ass. Prof.	13	4,85	0,376	0,104
	Assoc. Prof	18	4,61	0,502	0,118
	Prof.	18	4,39	0,778	0,183
	Total	72	4,49	0,712	0,084
Derivatives and their application	Research assistant	17	4,18	1,131	0,274
	Dr	6	4,33	0,816	0,333
	Ass. Prof.	13	4,54	0,519	0,144
	Assoc. Prof	18	4,61	0,502	0,118
	Prof.	18	4,44	0,616	0,145
	Total	72	4,43	0,747	0,088
Integration (Indefinite integrals, definite integrals, application of integrals)	Research assistant	17	3,88	1,269	0,308
	Dr	6	4,5	0,548	0,224
	Ass. Prof.	13	4,54	0,66	0,183
	Assoc. Prof	18	4,5	0,514	0,121
	Prof.	18	4,39	0,608	0,143
	Total	72	4,33	0,822	0,097
Vectors in space (three dimensional), operations and vectors	Research assistant	17	4,18	1,237	0,3
	Dr	6	4,17	0,408	0,167
	Ass. Prof.	13	4,69	0,48	0,133
	Assoc. Prof	18	4,06	0,938	0,221
	Prof.	18	4,22	0,647	0,152
	Total	72	4,25	0,868	0,102
Plane in space and analytic properties	Research assistant	17	4	0,791	0,192
	Dr	6	3,5	0,837	0,342
	Ass. Prof.	13	4,31	0,48	0,133
	Assoc. Prof	18	3,72	1,018	0,24
	Prof.	18	4,28	0,752	0,177
	Total	72	4,01	0,831	0,098

APPENDIX N: IBDP results for departments

	Department	N	Mean	Std. Deviation	Std. Error Mean
Finite random variables	E.E	30	3,33	1,093	0,2
	C.S	42	3,98	0,811	0,125
Statistical distributions (binomial, poisson, chi-squared, and normal distributions)	E.E	30	3,33	1,184	0,216
	C.S	42	4,05	1,058	0,163
Bayes theorem	E.E	30	3,47	1,306	0,238
	C.S	42	4,07	0,894	0,138
Significance and hypothesis testing	E.E	30	3,37	1,402	0,256
	C.S	42	3,93	0,947	0,146
Correlation and regression	E.E	30	3,47	1,306	0,238
	C.S	42	3,71	1,154	0,178
Interest, depreciation and cost	E.E	30	2,63	1,351	0,247
	C.S	42	3,1	1,031	0,159

APPENDIX O: IBDP results for universities

	Institution	N	Mean	Std. Deviation	Std. Error Mean
Finite random variables	METU	37	3,73	1,097	0,18
	Bilkent	35	3,69	0,867	0,147
Statistical distributions (binomial, Poisson, chi-squared, and normal distributions)	METU	37	3,73	1,283	0,211
	Bilkent	35	3,77	1,031	0,174
Bayes theorem	METU	37	3,78	1,336	0,22
	Bilkent	35	3,86	0,845	0,143
Significance and hypothesis testing	METU	37	3,73	1,367	0,225
	Bilkent	35	3,66	0,968	0,164
Correlation and regression	METU	37	3,62	1,32	0,217
	Bilkent	35	3,6	1,117	0,189
Interest, depreciation and cost	METU	37	2,76	1,321	0,217
	Bilkent	35	3,06	1,027	0,174

APPENDIX P: IBDP results for academic ranks

		N	Mean	Std. Deviation	Std. Error
Finite random variables	Research assistant	17	3,24	1,033	0,25
	Dr	6	4,17	0,753	0,307
	Ass. Prof.	13	3,92	1,115	0,309
	Assoc. Prof	18	3,61	0,916	0,216
	Prof.	18	3,94	0,873	0,206
	Total	72	3,71	0,985	0,116
Statistical distributions (binomial, Poisson, chi-squared, and normal distributions)	Research assistant	17	3,71	1,263	0,306
	Dr	6	4,5	0,837	0,342
	Ass. Prof.	13	3,85	1,144	0,317
	Assoc. Prof	18	3,44	1,294	0,305
	Prof.	18	3,78	1,003	0,236
	Total	72	3,75	1,16	0,137
Bayes theorem	Research assistant	17	3,82	1,38	0,335
	Dr	6	4,33	0,816	0,333
	Ass. Prof.	13	4	1,08	0,3
	Assoc. Prof	18	3,5	1,043	0,246
	Prof.	18	3,83	1,043	0,246
	Total	72	3,82	1,117	0,132
Significance and hypothesis testing	Research assistant	17	3,53	1,463	0,355
	Dr	6	4,17	0,753	0,307
	Ass. Prof.	13	4	1,08	0,3
	Assoc. Prof	18	3,5	1,295	0,305
	Prof.	18	3,67	0,97	0,229
	Total	72	3,69	1,182	0,139
Correlation and regression	Research assistant	17	3,35	1,656	0,402
	Dr	6	4,5	0,548	0,224
	Ass. Prof.	13	3,62	1,121	0,311
	Assoc. Prof	18	3,5	1,15	0,271
	Prof.	18	3,67	0,97	0,229
	Total	72	3,61	1,217	0,143
Interest, depreciation and cost	Research assistant	17	2,29	1,047	0,254
	Dr	6	3,33	0,816	0,333
	Ass. Prof.	13	3	0,913	0,253
	Assoc. Prof	18	3,22	1,478	0,348
	Prof.	18	2,94	1,162	0,274
	Total	72	2,9	1,189	0,14