INTEGRATION OF SCIENCE INTO MATHEMATICS IN THE HIGH SCHOOL CURRICULUM: A DELPHI STUDY

A MASTER'S THESIS

BY

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THE PROGRAM OF CURRICULUM AND INSTRUCTION
BILKENT UNIVERSITY
ANKARA

MAY 2012

INTEGRATION OF SCIENCE INTO MATHEMATICS IN THE HIGH SCHOOL CURRICULUM: A DELPHI STUDY

The Graduate School of Education

of

Bilkent University

by

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In Partial Fulfillment of the Requirements for the Degree of

Master of Arts

The Program of Curriculum and Instruction
Bilkent University
Ankara

May 2012

BILKENT UNIVERSITY
GRADUATE SCHOOL OF EDUCATION
INTEGRATION OF SCIENCE INTO MATHEMATICS IN THE HIGH SCHOOL CURRICULUM: A DELPHI STUDY
SUPERVISEE: TUĞBA AKTAN
May, 2012

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

INTEGRATION OF SCIENCE INTO MATHEMATICS IN THE HIGH SCHOOL CURRICULUM: A DELPHI STUDY

Tuğba Aktan

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Supervisor: Asst. Prof. Dr. Minkee Kim

May 2012

The focus of this study is to examine opinions about the implementation of the curriculum integration of mathematics and science (CIMAS). For this purpose, the study aims to explore possible mathematics topics for CIMAS and reach a consensus about advantages, disadvantages, and limitations of implementation of CIMAS. To achieve the consensus, a Delphi study was conducted with experts with regard to curriculum integration. The experts were university academics and school teachers in Ankara. The research produced a number of key findings: almost each unit in mathematics can be integrated with science; physics seems more feasible for integration with mathematics; CIMAS is perceived to increase student motivation and positive attitudes toward mathematics, to provide meaningful learning anda more effective teaching environment for school teachers. Although CIMAS is not seen to have disadvantages that hinder learning and teaching, the integration has limitations related to curriculum, teachers, and facilities that are obstacles to effective implementation. The main conclusions drawn from this study were that the integration of mathematics and science curriculum is expected to provide advantages and satisfy the psychological, pedagogical, and sociological needs of students. The findings could be valuable for curriculum developers, teachers, and teacher educators.

Key words: Mathematics education, science education, curriculum integration of mathematics and science (CIMAS), alternative methods for teaching high school mathematics

ÖZET

LİSE MÜFREDATINDA MATEMATİK VE FEN BİLİMLERİNİN ENTEGRASYONU: DELFİ ÇALIŞMASI

Tuğba Aktan

M.A., Eğitim Programları ve Öğretim Programı
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Mayıs 2012

Bu çalışmanın odağı, matematik ve fen bilimleri müfredatı entegrasyonunun (CIMAS) uygulanması hakkında uzman görüşlerini incelemektir. Bu amaçla, çalışma entegrasyonun yapılabileceği matematik konuları ve entegrasyonun uygulanmasının avantajları, dezavantajları ve sınırlılıkları hakkındaki düşünceleri inceleyecektir. Uzmanlar arasında uzlaşma sağlamak için, bu çalışma Delfi yöntemi kullanılarak yürütülmüştür. Ankara'da bulunan katılımcılar üniversitelerdeki akademisyenlerden ve lise matematik öğretmenlerinden seçilmiştir. Araştırmada önemli bulgulara ulaşılmıştır: Neredeyse matematikteki her ünite fen bilimleriyle entegre edilebilir; fizik konuları matematik entegrasyonu için daha uygundur. CIMAS öğrenci motivasyonunu ve matematiğe karşı olumlu tutumu artıran, anlamlı öğrenmeyi ve öğretmenler için etkili öğretim ortamını sağlayan bir araçtır. CIMAS'ın öğrenme ve öğretme sürecine engel olan önemli dezavantajları görülmese de, entegrasyonun etkili bir şekilde uygulanmasına engel olan müfredat, öğretmen ve olanaklar ile ilgili sınırlılıklar vardır. Bu araştırmadan çıkarılan başlıca sonuç, matematik ve fen müfredatı entegrasyonun faydalı bulunması ve müfredat geliştirme sürecinde dikkate alınması gereken, öğrencilerin psikolojik, pedagojik ve sosyolojik ihtiyaçlara cevap veriyor olmasıdır. Bulgular müfredat geliştiriciler, öğretmenler ve öğretmen eğitimcileri için değerlidir.

Anahtar kelimeler: Matematik eğitimi, fen bilimleri eğitimi, matematik ve fen bilimleri müfredatı entegrasyonu(CIMAS), lise matematiği öğretimi için alternatif yöntemler

ACKNOWLEDGEMENTS

Foremost, I would like to express my sincere gratitude to Prof. Dr. Ali Doğramacı, Prof. Dr. M. K. Sands and everyone at Bilkent University Graduate School of Education for providing us with a good environment and facilities to complete this study.

I would like to offer my sincerest appreciation to my supervisor Asst. Prof. Dr. Minkee Kim. This thesis would not have been possible without his help, support and patience. I feel motivated and encouraged every time I attend his meeting. I would like to express my special thanks to Prof. Dr. Alacacı who provided me full support for this study with his valuable comments and contributions.

I would also like to thank to the Delphi Technique panelists who spent their time and energy to make this study possible.

Personal thanks go to my valuable friends who always support me with their adoring hearts. I will always feel their support in my whole life.

Lastly, my heartfelt thanks and appreciations go to my family who makes my life meaningful with their endless and worthless love and support.

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CHAPTER 1: INTRODUCTION

Introduction

In this information age, students are expected to produce new ways of thinking that is different from traditional ways, and construct new relations between reasons and results in understanding and dealing with phenomena. They need to know how they are going to reach the information and think reasonably and critically to be ready to have a valuable place in society. In the 21stcentury, people need to solve more complex problems such as global warming or producing a multifunctional product with the lowest price. Such problems have to be considered from more than one point of view; and integrating the views of different disciplines is required to solve such complex problems. In this light, the parallelism between the education in schools and the expectation of society necessitates the changes and the developments in curriculum (Numanoğlu, 1999). In the globalizing world, current problems will be solved with a multi-disciplinary approach that coordinates and combines the information, concepts and ability in different disciplines (Balay, 2004).

Background

Integrating disciplines is not a newly emerging concept, but has become more popular since the late 1980s (Drake, 2007). Its origins go back to ancient times. The ideas of Aristotle, Pluto, Kant, Hegel and other historians, who have been known as *interdisciplinary thinkers*, were the early pioneers of integrating disciplines. Until the 20thcentury in education, the concept was not frequently employed,despite its long history(Klein, 1990).At the end of that century, curriculum integration started to appear in education, in K-12 with different designs that linked more than one discipline and integrated units, themes, and objectives(Klein, 2005).

According to historians, there were four important curriculum development efforts in the history of Turkish education system. The first milestone was from Atatürk's contribution to curriculum that was started with the revolution of the alphabet (1926). The second milestone was John Dewey's impact. The curricula of 1930 and 1938 were affected by the reports of Dewey. The effects of policy changes at both national and international level were the third important milestone in curriculum developments in history(Argün, Arıkan, Bulut, &Sriraman, 2010). Before World War II, educational studies were affected by the dominance of Germany. After the war, the changing relationships between the countries and with the emergence of USA, Turkey accepted USA, the most powerful country in the Western world, as a model in its educational institutions (Under, 2008). The last milestone according to Argün et al. was the increasing role of academics and MoNE (Ministry of National Education). From the 1960s to the present, many changes have been implemented with the increase of the number and quality of the research in education. However according to public opinion, the attempts on curriculum improvement have not produced sufficient results in Turkey yet (Argün et al., 2010).

The great developments of science and technology in the last century direct the country's focus on mathematics and science education in their education policy. For example, although there were important developments in mathematics and science education in the twentieth century, the research about mathematics education in Turkey has increased since the 1990s. This shows that the educational system in

Turkey is at the developing level in terms of the area of education and there should be more empirical research about mathematics education across various grades(Tatar & Tatar, 2008; Ubuz&Aşkar, 1999).For example, according to a document analysis by collecting keywords from articles about the research on mathematics education in Turkey, 221 different keywords were found and the keyword “modeling” was encountered with a very low frequency of one percent(Tatar & Tatar, 2008, p. 100). Modeling is a desired part of mathematics education. It provides students meaningful understanding and is an important approach to integrate mathematics and science (MoNE, 2011).

Today, mathematics is perceived as a way of modeling reality with problem solving and analysis rather than memorizing abstract terms and skills. There are two emerging approaches in mathematics education, constructivist learning and the realistic mathematics education. Both of them aim to make mathematics more meaningful with understanding knowledge, and direct experiences and abilities (Altun, 2006). Moreover, our National Mathematics Program for high school (MoNE, 2005b) aims to teach mathematical thinking and reasoning skills such as problem solving and apply these skills to real life problems. Mathematics is a part of our culture and a social phenomenon in our society, nature, and other disciplines. In this sense, mathematical modeling, especially in other disciplines, have an important place as a means of providing students to learn constructing the logical relations and gaining the abilities of related abstract thinking (MoNE, 2005b). However, a centralized exam system is the main factor that is threatening for such desired learning environments because of giving importance to results rather than processes(Altun, 2006, p. 234). The university entrance exam at the end of the four year-high school has unfortunately affected the secondary education in an adverse way tremendously (Argün et al., 2010).

One of the major curriculum issues in Turkey is said to be curriculum integration (Paykoç et al., 2004). According to Coştu et al.(2009, p. 1696), students in Turkey believe that giving information about why they need to learn and where it is used would be beneficial and helpful for them. The literature addresses constructing relations between high school mathematics curriculum (see Table 1) and science curriculum and accordingly developing curriculum and textbooks (MoNE, 2011).

Table 1
Turkish national high school mathematics curriculum

9th Grade	**10th Grade**	**11th Grade**	**12th Grade**
-Logic -Sets -Relation, function, and operation -Numbers	-Polynomials -Quadratic equations, inequalities, functions -Permutation, combination, probability, statistics -Trigonometry	-Complex numbers -Logarithms -Induction and series -Matrices, determinant and system of linear equations	-Functions -Limit and continuity -Derivative -Integral

Problem

The growth of knowledge requires more relations between mathematics and other disciplines in mathematics education (Loepp, 1999); therefore, our curriculum should meet the changing world's expectations. In this light, one of the important considerations that should be taken by educators is to be aware of the expectations of society and the trends and innovations about curriculum development for the future of Turkish high school curriculum. Curriculum, schools, classes, and teachers need to reflect the changing world that is why our high school curriculum needs to be improved to address the needs of the information age.

In the 21^{st}century, although the Turkish students are expected to develop problem solving skills within the light of the constructivist approach (Jacobs, 1989), students have difficulties to understand mathematics because the textbooks and the teaching techniques are not connected to its applications. A curriculum becomes more relevant to everyday situations, if the mutual connections between subjects are integrated (Hoaclander, 1999; Wicklein& Schell, 1995).Another important issue different from the content of curriculum is the university entrance exam. This type of centralized exam is a barrier to achieving the desired learning and teaching environment and it causes creates a need for memorizing (Altun, 2006, p. 234). Curriculum integration requires personal construction of knowledge instead of memorizing and following specific steps to solve problems and it allows students to work together in a creative and critical way (Özdemir&Ubuz, 2006).

Purpose

The general aim of this study is to elicit experts' opinions about the implementation of the curriculum integration of mathematics and science (CIMAS). For this purpose, this study aims to identify the appropriate high school mathematics' topics for integration with science according to experts' opinions. For this, the study aims to explore the relations between the sociological, psychological, and pedagogical needs that should be considered in curriculum design with consequences of the curriculum integration process. Moreover, the study aims to get possible reasons behind the perceived limitations and disadvantages of integration. As a type of expert survey, a

Delphi study was conducted with university academics and school teachers, concerning curriculum integration; their opinions contribute to this study with both a theoretical approach provided by academics and practical approach provided by teachers. The analysis employed both qualitative and quantitative approach.

Research questions

This study addresses the following questions:

How do academics and mathematics teachers perceive integration of science into the mathematics curriculum in the Turkish context?

Sub-questions are as follows:

1. What could be the possible topics in mathematics that are appropriate for science integration?
2. How do the experts perceive advantages, disadvantages, and limitations of integration of science into mathematics?

Significance

Since the research aims to examine opinions of experts about the features of implementation process of integrated curriculum by using the Delphi method and so the experts' opinion, the study is found valuable by teachers, administrations, curriculum developers and teacher educators. By this way, they are aware of possible topics that can be integrated with science; teachers can get benefit to prepare their lesson in the lights of given examples. The perceived limitations of integration show the important points that curriculum developers should be careful on. Moreover, teacher educators can improve the teacher training programs by taking into consideration of perceived advantages of integration. Therefore the study provides benefits which aim to enhance the learning environment for students. Additionally, this study is highlighted since that it is carried out in Turkey and presents the features of implementation process of integrating curriculum under Turkish context. With the results and discussion of this study, the consensus of experts contributes to the developing education system in Turkey.

Limitations

The findings in this study are limited to participants who attend the rounds of the series of surveys. Since the method of this study is the Delphi technique, the sample is purposeful. This study collected the opinion of academics and teachers in Ankara. Although this study reached a consensus among the participants, it is difficult to make generalization with the limited sample. In addition, the quality of the responses and the detailed qualitative analysis was important for the next panels' survey. The distribution of the number of academics and teachers in the sample were not even, the teachers constituted approximately 70% of the experts. Therefore, the results can be perceived as representative for the teacher's opinion. In the same proportion, still the results provide valuable information about the features of implementation process of the curriculum. The last limitation concerns the grouping of suggested science topics under each unit from a mathematics perspective. In fact, the main focus of this study was to investigate the appropriate mathematical topics for science integration, not to investigate the science topics for mathematics integration.

Definition of key terms

There are some key terms about degree of integration that should be examined moreover analysis of the differences between disciplinary and non-disciplinary approaches is required. In addition to this, there are two types of non-disciplinary approached that are often confused with each other: multidisciplinary and interdisciplinary.

Disciplinary approach as Piaget proposed, is a specific discipline taught based on its own background knowledge, techniques, ways and content areas such as a classic mathematics lesson (as cited in Jacob, 1989). Besselaar and Heimeriks (2001) define *disciplinary approach* as "It is 'normal problem solving' within a 'paradigm', and with hindsight we can define the boundaries of disciplinary fields."(p.2). Therefore, in this study, disciplinary approach is defined as a description of knowledge, skills, problems, methods, and studies that is related to one academic area only.

Non-disciplinary approach, on the other hand, combines elements from various disciplines and their interactions (communication and comparison of ideas, data, procedures and methods), in order to solve practical problems (Besselaar&Heimeriks, 2001).When learning activities are designed and implemented by combining more than two concepts, their integration should be considered. Non-disciplinary curriculum can contain both integration-based activities and discipline-based activities (Lonning&DeFranco, 1997). Interdisciplinary and multidisciplinary are two types of integrating knowledge that can be considered as non-disciplinary approaches these approaches allow the interactions between disciplines based on the common problems and issues.

Multidisciplinary approach is stated as "in multidisciplinary research, the subject under study is approached from different angles, using different disciplinary perspectives. However, neither the theoretical perspectives nor the findings of the various disciplines are integrated in the end."(Besselaar&Heimeriks, 2001, p. 2).This approach concerns in a topic in more than one discipline. Put differently, although the aim of this approach is limited to the framework of a disciplinary research, it is more than the boundaries of one discipline (Nicolescu, 1999). It is not required to integrate disciplines directly. Rather, these disciplines are used in sequential or juxtaposed mode (Klein, 2006). Generally, multidisciplinary approach provides the help of other disciplines by providing different perspectives without totally integrating the principles of other disciplines.

Interdisciplinary approach is defined as a curriculum understanding that consciously applies to the methodology and terminology from more than one area of science to examine a specific topic, problem, issue, or experience. In contrast to discipline-focused approaches, interdisciplinary approaches provide more connections (Jacob, 1989). Compared to such a disciplinary course, an interdisciplinary course can be considered as application-oriented course. For example, discovering theoretical knowledge about physical nature in a disciplinary field is not the general aim of a interdisciplinary approach. Rather, studying applications as a production of knowledge is its main interest. In this approach, various organizational structures, problems, and research are involved. An interdisciplinary approach hints at the significance of use importance to the usage of knowledge for the sake of society (Gibbons, Limoges, &Nowotny, 1997).

Moreover, the goal of an interdisciplinary approach is different from a multidisciplinary approach. The former aims to transfer instructional methods from one discipline to another (Besselaar&Heimeriks, 2001; Nicolescu, 1999). In summary, the interdisciplinary approach is beyond segmented interactions occurring in different disciplines. The approach is an integration of the knowledge, methods, and studies.

To summarize, there is considerable difference between non-disciplinary and disciplinary approaches. In the latter category of non-disciplinary approaches, there are interdisciplinary and multidisciplinary approaches. While the former is defined as an integration of knowledge from different disciplines, the latter does not require as much as integration. The relation between disciplines in the multidisciplinary approach is not as much as interactive in the interdisciplinary approach. In the former approach, students will be asked to consider views from different disciplines and not to study too much on direct assembly of knowledge.

CHAPTER 2: REVIEW OF RELATED LITERATURE

Introduction

The literature review provides the background information about how integrated knowledge has built its importance through previous studies in research literature. First, common opinions about mathematics and science integration are given, and then models for integration are discussed. Second, psychological, sociological, and pedagogical factors that affect the curriculum are discussed. Lastly, possible advantages and disadvantages with the limitations and barriers for applying in a non-disciplinary approach are discussed in order to shed light into both positive and negative aspects of the approach.

Importance of mathematics and science integration

Generally, mathematics lessons seem detached from the connections between other disciplines and real life; it is isolated with its own traditional textbooks, tests and instructions different from many other subjects. Mathematics supported with scientific concepts could increase the understanding of the physical universe (Kleiman, 1991). In practice, science and mathematics are not only conceptually interwoven but also feasibly complimentary to each other. The integration between these disciplines concerns the real world applications and is believed to motivate students (Frykholm& Glasson, 2005).

Models for integration

There is more than one way to integrate curricula. Fogarty (1991) categorized different approaches as sequence, shared, webbed, threaded, and integrated models (Figure 1). Fogarty likens the sequence model to eyeglasses. There are two different disciplines depicted as the lenses and the lenses are connected to each other with a framework. For example, the biology unit, genetics, and the mathematics unit, probability might be taught in different or linked classes when designed in the sequenced model.

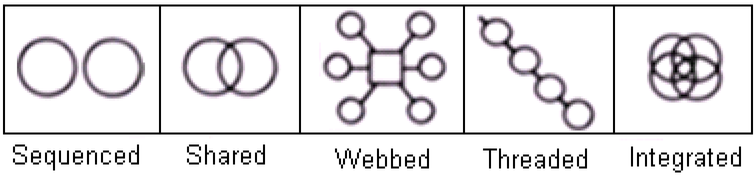


Figure 1.Five ways to integrate curriculum across several disciplines (Fogarty, 1991)

The shared model is likened to binoculars. Again, there are two different disciplines; differently from the eyeglasses, the focus is just one. In terms of integration of disciplines, a common unit is specified for more than one discipline and the cooperative work between the teachers is necessary to point out the similar and different views. The webbed model is similar to a telescope that supplies a broader view of the constellations such as various elements are webbed to a theme. The common theme is described by different disciplines. The threaded model is depicted as a magnifying glass that helps to enlarge the ideas of the all the disciplines while it is improving social skills, reading skills, thinking skills prediction skills etc. in all other disciplines. Last, the integrated model likens to a kaleidoscope that symbolizes overlapping the topics and concepts around an interdisciplinary unit (Fogarty, 1991; Kysilka, 1998).

For science and mathematics integration, several integration models exist. Huntley(1998) divides the integration into five categories; mathematics for the sake of mathematics, mathematics with science, mathematics and science, science with mathematics and science for the sake of the science. In line with this, Lonning and DeFranco (1997) established another model for mathematics and science integration. This continuum model of the integration presents five varied steps; independent mathematics, mathematics focus, balanced mathematics and science, science focus, and independent science. The independent mathematics and the independent science models include integration only within disciplines. In a mathematics focus and a science focus, science or mathematics is the focus; other discipline is the supportive of the focus. The role of the disciplines is equally distributed in balanced mathematics and science.

This study addresses the integration model *science into mathematics* where in mathematics is located in the center and science is used to develop the meaningful understanding of mathematics. This is similar to the models, the mathematics focus, and mathematics with science. This integration can also find its relevance in the multidisciplinary approach, while this approach provides students with two-dimensional thinking. They need to work on two dimensions by simultaneously focusing on the whole and the parts. The idea is in line with the idea of thinking connections and distinctions (Drake, 2007).

Need for integrated curriculum

Curriculum is an essential and significant part of education. It is changed and improved day by day based on research and is also affected by different trends and conditions. Thanks to the previous studies, curriculum is considered with students' needs and more attention is paid to integrated knowledge.

As an example of research, it is found that students in social studies have difficulties in understanding, reading, interpreting and creating graphs; guessing or estimating graphs. Therefore, to improve their academic achievement, social studies must evaluate the mathematical issues that help to develop students' competency in their special area. Therefore, infusing mathematics into social studies could provide a better understanding in that area (Mauney, 1998)..

Mauney (1998) chose two topics, geometry and statistics, that are related to real life learning most. She prepared her lesson with the strong connections of social studies that they could be mostly engaged with geometry and statistics. Preparing a lesson with the help of mathematics to develop students' competencies in social sciences is very important because according to the multiple intelligence theory, one intelligence can be improved by the development of other intelligences (Mauney, 1998). She observed all these activities and discovered more ways to bring math into the social studies classrooms. All these observations provide support for integrated curriculum. The needs that should be met by school curriculum can be categorized as sociological, psychological, and pedagogical needs (Robitaille and Dirks, 1982).

Sociological needs

Developments in modern society require connecting different disciplines. If the education is considered within a sociological context, it can be contended that education should be linked to expectations of society. Hence, the growth of knowledge requires interdisciplinary approach in mathematics education in the information age (Jacobs, 1989; Kaya, Akpınar, &Gökkurt, 2006).The problems that citizens, workers, or family members face are not always similar tothe problems in the textbooks from a discipline. Integrative thinking provides people with knowledge in unexpected situations (Klein, 2005, p. 10).

The following metaphor summarizes society's response to the fragmentation as a need for non-disciplinary approach, "A doctor cannot be trained only in the psychology and biology of the body; a doctor treats the whole human being." (Jacob, 1989).In addition, especially mathematics and science integration have a social significance in today's information age. It is claimed that the successes in mathematics and science are accepted as an indicator of a success of the education system and an indicator of development of the society (Cosentino, 2008).

Psychological needs

Students' generally complaint about learning mathematics is that it is taught in a way that is disconnected to the real world (Jacobs, 1989). Some general questions of students are 'Why do we need to learn mathematics?' and 'Where will we use it?' When they could not find answers to these questions, this situation might have concluded with the lack of motivation in learning environment for them. Therefore, the applications and the presented aims of scientific subjects are the primary expectation of students when they have difficulty in learning them. Klein (2005) emphasized the importance of integrating disciplines, "Students are engaged in making meaning." (p.10). When considered from this point of view, curriculum should be developed with real life situations so as to increase students' motivation and the learning activities in mathematics should be related to other disciplines (Hoaclander, 1999).The integration of science and mathematics, which contain more abstract concepts than other disciplines, provides students more chances for applications of the concepts to be learned(Cosentino, 2008).

Pedagogical needs

Integrated curriculum provides opportunities for intellectual curiosity, critical thinking, and problem solving skills with real world applications (Loepp, 1999;Wicklein& Schell, 1995). This approach has been discussed to require constructivist instruction instead of memorizing and following prescribed steps (Kaya et al., 2006; Klein, 2005; Loepp, 1999).

In addition to these, the non-disciplinary approach that can be accepted as an innovation in curriculum design requires teachers' effort in their teaching to be creative. By this way, the students are able to achieve a higher level of learning and develop appreciation of the topics to be learned (Wicklein& Schell, 1995).This intersection of two disciplines provides students with the ability to overcome complex issues and problems, to create a broader framework by comparing and constructing the ideas and building connections from different perspectives (Klein, 2005, p. 10).In addition, mathematics and science integration can improve the performance of students in open-ended tasks (Cosentino, 2008, p. 33).

Curriculum integration between science and mathematics in schools

Advantages

Different from a disciplinary approach, non-disciplinary approaches that highlight curriculum integration, provide a learning environment that has a broader context of student learning (Loepp, 1999), although some argue that the broader context may cause limitations of learning due to the difficulties for students to identify important concepts listed in a curriculum (Wicklein& Schell, 1995). In various studies, such difficulties have been overcome by carefully-designed lessons and learning objectives.

Since mathematics and science are complimentary disciplines, their integration of them is also feasible and their integration overlaps with real world applications and it helps to motivate students (Frykholm& Glasson, 2005).In other words, it is good for students to improve motivation to attend class because students will develop awareness of the necessity and the importance of mathematics in real life (Loepp, 1999). Students often have difficulties understanding mathematics when textbooks are isolated from its applications. As a non-disciplinary approach that offers connections between subjects, the curriculum becomes more relevant to students (Jacobs, 1989). In addition, a non-disciplinary approach is helpful to foster the cooperation of teachers and the relationship between them (Wicklein& Schell, 1995).

Although integrated disciplines require extra effort, it has important benefits. It does not only help students to motivate but also helps them get higher scores in mathematics and science lessons (Cosentino, 2008, p. 72). According to some research, this approach helps students to gain intellectual curiosity, critical thinking, problem solving skills and academic achievement (Loepp, 1999). The integration between science and mathematics not can help improve a notable achievement in mathematics, but the approach can also improve recognizable evidence on students' notable achievement in science. As a matter of fact, with the integrated design of science and mathematics, students' achievement in science was highest when it was taught in conjunction with mathematics. Therefore, it can be said that the integration of mathematics and science has positive effects on the achievements of students in science(Cosentino, 2008; Hurley, 2001; Mupanduki, 2009).

Moreover, non-disciplinary approach that integrates more than one discipline provides the usage of teacher's skill in a creative way (Wicklein& Schell, 1995). Also, the cooperative works between teachers in the progress of integration enhance their creativity of them and hence enriches the lessons.

Learning is not only a mental process but also a biological process. According to Hebb, without knowing the workings processes and principles of the brain, the nature of learning cannot be understood (as cited in Keleş&Çepni, 2006). If biological structure and working system of brain are understood, brain based education could provide a step for meaningful learning instead of memorizing information (Caine & Caine, 1990).Mapping between neurons is required in order for meaningful learning to occur. It symbolizes the connections between knowledge that are already known and newly known (Keleş&Çepni, 2006). Enriching the environment with stimulus helps to provide meaningful learning. Integration of schools curricula is important in this sense; educators should integrate subjects such as mathematics, science, history, and chemistry. As doing so requires, using both lobes of the brain increases the learning capacity of brain more than twice (Caine & Caine, 1990).

In mathematics and science integration; students need to use not only the cognitive knowledge to make logical order, decision, calculations and analysis but also the attitudinal knowledge that performs creativity, interprets the visual with open-ended ideas and uses intuitions which is controlled by different lobes of brain(Boydak, 2004). Therefore, integration is a valuable strategy to provide meaningful learning and increase the capacity of brain. While designing a curriculum, learning should also be accepted as a biological process, and educators need to take into consideration the structure, nature and processes of the brain.

Constraints on implementation

The approaches that integrate more than one discipline may also result in limited learning (Wicklein& Schell, 1995). The students may not catch important points in the lessons. In order to prevent these possible problems, the objectives of a lesson should be directly related the topics that are connected and given clearly to students.

It is known that there is more than one definition for integration; therefore, their multitude of approaches may cause difficulties and challenges while designing a program that integrates science and mathematics (Cosentino, 2008). Planning lessons in the light of integrated knowledge require much responsibility from teachers and administrators. Teachers and administrators must effectively collaborate to design an integrated curriculum. This collaboration is an essential factor. They should work together to accomplish their aims. Since this type of collective work requires more effort, the responsibility to create smooth coordination when both disciplines belongs to the teachers and administration (Wicklein& Schell, 1995). That is, teachers need to become more skilled and need to knowledgeable about multiple subjects (Loepp, 1999). It is expected that they are capable in different subject areas and use a diversity of learning and teaching techniques within these areas. For example, using technology in mathematical modeling of real life situations is an important constitution.

In general, due to the lack of planning time, evidence to support to teachers, and lack of uniform definitions of integration, plus assessment issues are barriers to the implementation of integrated knowledge(Cosentino, 2008; Satchwell&Loepp, 2002). Therefore, to use integrated curricula effectively requires strong support from administration (Satchwell&Loepp, 2002).

To summarize, the literature review addressed the importance of science and mathematics integration, and the importance of the integrated knowledge from different perspectives, such as sociologically, psychologically, and pedagogically. Although integrated disciplines have an important place in education with advantages such as in motivation and achievement, the literature review also identifies the difficulties and barriers to integrate disciplines as well. The approach to curriculum integration has been perceived as difficult for both students and teachers (Wicklein& Schell, 1995). In order to overcome these difficulties, one of the most important factors is cooperative work between teachers and administrators. Generally, in this chapter, available research about the integration of mathematics and science are summarized.

The purpose of this study is to investigate the importance and to examine the effects of integrated disciplines on students learning and thinking processes as perceived by experts. The research tries to provide an answer as to how mathematics can be made more meaningfully and more effective for high school students if mathematics is taught in scientific context. On that point, the literature review shows different ways to understand different conceptions of integrated disciplines. Social, psychological, and pedagogical perspectives help to see integrated knowledge from different angles.

Moreover, attitudes from teachers, students and administrators help to see the advantages and barriers while applying the integration. The last part of the literature review summarizes findings about the integration of mathematics and science as related to research questions. More specifically, the research is about curriculum integration of mathematics and science (CIMAS) (Figure 2) in high schools. Integrating disciplines has not been tried before in Turkey; the study looks into the applicability of this idea in Turkish high schools.

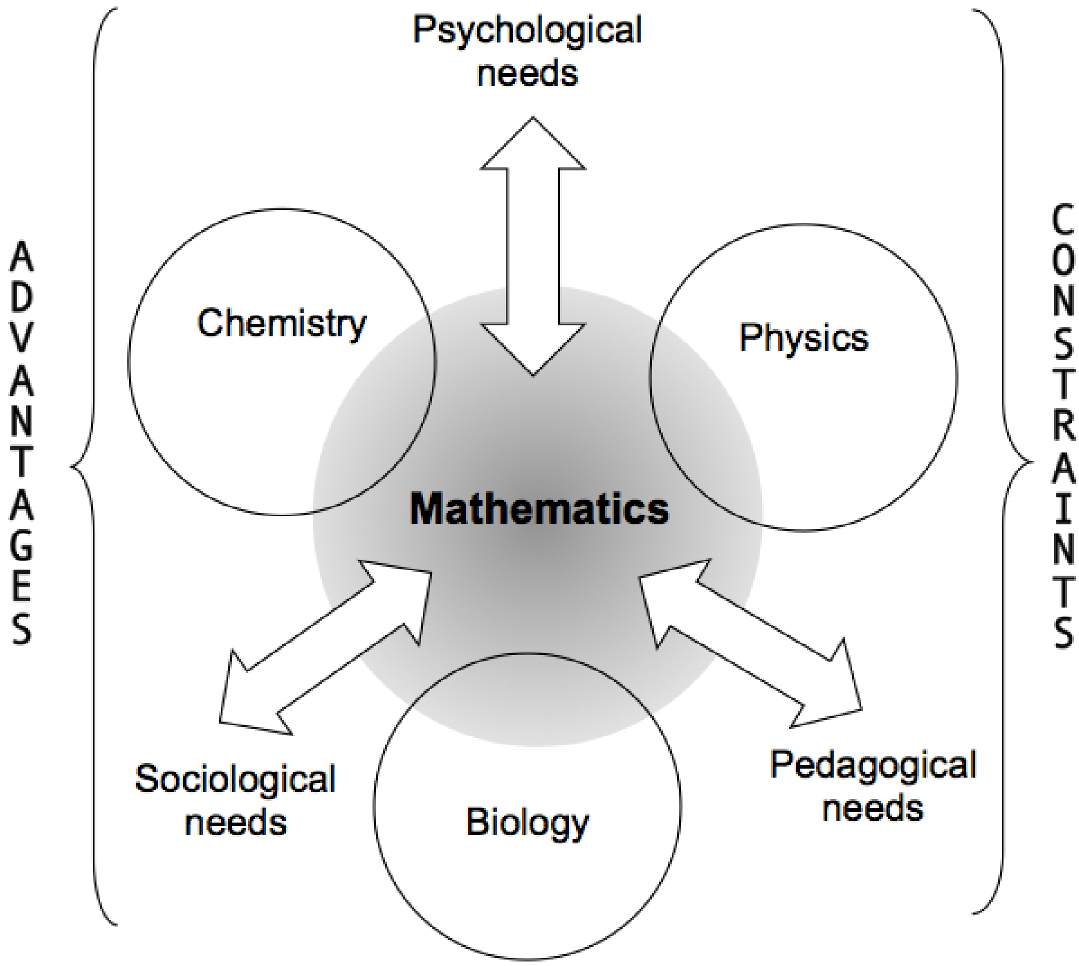


Figure 2. A model of curriculum integration for mathematics and science integration (CIMAS)

CHAPTER 3: METHOD

Introduction

The purpose of this Delphi study was used to investigate the importance of the non-disciplinary approach in mathematics curriculum as perceived by experts. The Delphi approach, which is a group communication process with controlled feedback, was appropriate for the purpose of the study to achieve consensus about the experts' opinion about the process of integrated curriculum. Surveys, as given in Appendices A through K, were used to seek possible topics for integration, advantages, disadvantages, and limitations of an integrated curriculum. The study was based on the opinions of academics and teachers in Ankara.

Research design

Developed by the Rand Corporation in the 1950s, the Delphi technique is a method for "… systematic solicitation and collation of judgments on a particular topic through a set of carefully designed sequential questionnaires interspersed with summarized information and feedback of opinions derived from earlier responses"(Delbecq, Van de Ven, & Gustafson, 1975, p.10). Since the Delphi study has plural rounds that consist of open-ended questions and surveys, in general, the method is considered as both a qualitative and quantitative approach. Time management is one of the possible constrains of this method because late responses from panel members may slow down the entire process (Wiersma&Jurs, 2009).

This study searched for the answer of the question “How do academics and mathematics teachers perceive integration of science into mathematics curriculum in Turkish context?” In this respect to get opinions and reach a consensus about the features of implementation process of integration, this study addressed the following sub-questions is as follows:

1. What could be the possible topics in mathematics that are appropriate for science integration?
2. According to experts, what will be the advantages, disadvantages and limitations of integration of science into mathematics?

Participants

The Delphi study required explicit criteria for choosing panel participants. The participants in this study were academics and teachers who were knowledgeable and experienced in teaching. Teachers at two private schools in Ankara with at least three years of experience, and academics with a doctoral degree in mathematics education and currently working in the Ankara region, participated in this study. A convenient sample strategy was used to select academics in mathematics education with doctoral degrees in the field from the Faculties of Education in Ankara.

It was important to get both teachers and academics’ opinions to examine both theoretical knowledge and its practical classroom applications. The first round survey aimed to reach 10 academics therefore first round survey was sent to 10 academics by e-mail with a cover letter to give a brief information about the aim of this study and its method (see Appendix A, B, and C). Only six academics responded the survey. Since the number did not seem enough, then the survey was also sent to five more academics. The number of academics increased to seven; then again to increase the number of sample, the first round survey e-mails were also sent to all academics in Ankara who had a doctoral degree to increase sample size but there were no additional responses. Some of them refused to complete the survey by stating that they did not have detailed information about high school mathematics curriculum. At the end of the communication process, seven academics voluntarily participated in the survey.

After the first round survey was approved by The National Ministry of Education, the survey was also approved by the two private schools. The first round survey was e-mailed to all the teachers in these schools. 13 teachers from one of the schools and three teachers from the other school responded to the first round survey.

The second round survey was created according to responses from the first round survey (see Appendix D, E, F, and G) therefore the second round questionnaire was sent to only the experts who responded to the first round survey. At the end of the second round, all experts who attended the first round responded to second round survey (see Appendix H, I, and J).As a result, 16 teachers and seven academics participated in the research.

Instrumentation

First round open-ended survey

The aim of this study was to reach a consensus about the features of implementation process of integrated mathematics and science curriculum, its advantages, disadvantages, and limitations. To get detailed information about the implementation process, experts' opinion on possible topics in mathematics were also researched. In the light of this aim the first round survey contained five open-ended questions (Table 2).

Table 2
First round (open-ended) survey questions

1.Appropriate topics for integrating mathematics and science
• Which topics in mathematics high school curriculum can be considered as appropriate for mathematics and physics integration? Please explain it with examples. • Which topics in mathematics high school curriculum can be considered as appropriate for mathematics and chemistry integration? Please explain it with examples. • Which topics in mathematics high school curriculum can be considered as appropriate for mathematics and biology integration? Please explain it with examples.
2.Possible advantages
• What could be the possible advantages of integration of science to mathematics for students' learning process? Please explain your opinions with examples.
3.Possible disadvantages and limitations
• In Turkish context, what could be the possible disadvantages and limitations of science to mathematics that affect students' learning process? Please explain your opinions with examples.

The questions for the first round attempted to get a wide range of opinions from experts including positive and negative aspects of integrated curriculum. The first three questions asked possible topics that were appropriate for the integration of mathematics and physics, chemistry and biology. The other two questions sought information about the advantages, disadvantages, and limitations in the Turkish context. To avoid using improper wording and ambiguity, the pilot questionnaire was administrated to two academics and five graduate students prior to actual. In this way, the need for validity of the questions was ensured and the time needed to respond the survey was found to be approximately 45 minutes.

Second round Likert scale survey

All suggestions except the questions asking examples of topics (see Appendix D, E, and F) from the first survey responses (see Appendix G, the results of which were summarized in English in Figure 4 and Figure 6) were used to prepare the second round Likert scale (see Appendix I).Opinions about advantages, disadvantages and limitations of integration were listed to be ranked as agree, disagree and no opinion. By the help of this Likert scale, rates of agreements on each statement were identified. In the second round, the participants presented their agreements and disagreements about opinions with the Likert scale by responding to the scale (agree-disagree-no opinion). Before sending them to the participants, the Likert scale was administrated to two academics and five graduate students again as in the first round, and their opinions were taken to avoid using improper wording and avoid ambiguity. By this way, the need for validity of the questions was addressed and also the needed time was found to be approximately 10 minutes to respond to the survey.

Method for data collection and analysis

Data were collected electronically using the Delphi technique. The questionnaires were prepared online and the link of the survey was sent by e-mail (see Appendix C and J). The general process contained two steps; Table 3presents the summary of the process.

First round survey. The first questionnaire contained five open-ended questions. The survey, containing questions related to appropriate topics of integration, benefits and constraints of integration was created by using Google documents. The link of the survey was e-mailed to the respondents (see Appendix A, B, and C) After a period of time, they were reminded to complete the survey by phone. The responses were obtained online. After the data were collected, they were analyzed qualitatively for the themes.

Table 3
Summary of the procedure of data collection and analysis

Participants	**Instrument**
1st round open-ended survey in December 2011	
The survey was sent to • 44 academics in Ankara • 33 teachers in the two private schools.	• First round survey contained 5 open-ended questions that address the research questions.
Responses from 1st round in January 2012	
The responses were collected from • 7 academics • 16 teachers in the schools	• Responses were analyzed using frequency distribution and chi-square test. • Responses for advantages and constraints were categorized and determined to be used for Likert scale survey
2nd round Likert scale survey in February 2012	
It was sent to • 7 academics • 16 teachers in the schools	• Second round survey contained 33 opinions with the scale (agree-disagree-no opinion) • 16 of them mentioned advantages under the subheadings • 17 of them mentioned constraints
Responses from 2nd round Likert scale survey in March 2012	
The responses were collected from • 7 academics • 16 teachers in the schools	• By calculating mean, ratings the degree of agreement on them was analyzed. • Comparison between categories was done by finding average mean

Responses of the first three questions were analyzed differently from the fourth and fifth questions which were used to create the second round Likert scale. All examples and topics were listed and then categorized under common headings as numbers, functions, trigonometry etc. (see Appendix D, E, and F). The title of topics counted and a frequency of the appropriate topics were calculated. Moreover, the distribution of the number of examples into physics, chemistry, and biology was analyzed to compare by using the chi-square test to find out whether there was a significant difference or not.

Responses of the fourth and fifth questions were also categorized under subheadings. The opinions of advantages were divided into four subheadings which were directly related to subtopics in the literature review. By the help of coding, all responses were grouped as psychological needs (Ps), pedagogical needs (Pd), sociological needs (SO) and other needs (Ot). After the general grouping of ideas, with two or more steps, opinions were narrowed and similar ideas were combined as one opinion. At the end of this analysis, six opinions under Ps, three opinions under Pd, four opinions under SO and three opinions under Ot were created. From the question investigating the advantages, 16 opinions were placed to be ranked in the second round Likert scale (see Appendix G and I).

Opinions of disadvantages and limitations were also divided into four subheadings. By the help of coding, all responses were grouped as constraints related curriculum (Cc), constraints related teachers (Ct), constraints related students (Cs), and constraints related facilities (Cf). After the general grouping of ideas, with two or more steps, opinions were narrowed and the similar ideas were again combined into unitary themes. At the end of this analysis, four opinions under Cc, five opinions under Ct, four opinions under Cs and four opinions under Cf were created as in Table 4. From the questions which investigated the disadvantages and limitations in the Turkish context, 17 opinions were placed to be ranked in second round Likert survey.

Table 4
Categories under advantages and constraints and their frequency

Advantages				**Constraints**			
Ps	Pd	SO	OT	Cc	Ct	Cs	Cf
6	3	4	3	4	5	4	4

Note. Ps, psychological needs; Pd, pedagogical needs; SO, sociological needs; Ot, other needs; Cc, constraints related curriculum; Ct, constraints related teachers; Cs, Constraints related students; Cf, Constraints related facilities.

Second round survey. The second questionnaire was developed from the responses from the first questionnaire that were analyzed qualitatively. This second round survey included Likert-scale items on the *Google docs*. The link to the survey was emailed to the respondents, and responses were again obtained online (see Appendix H, I and J). After that, the data were analyzed with the help of calculating mean of each statement. The mean directly gave the percentages of experts who agreed with the statements (see Appendix K).After calculating means, tables about the agreement on sentences were constructed with charts.

Final analysis of data. Responses from round two were analyzed to determine if there was a consensus by looking at the responses and their means. Means directly showed the degree of agreement of experts by percentages.

CHAPTER 4: RESULTS

Appropriate topics in high school mathematics curriculum for integration

The topics given by experts as appropriate for integration of science were listed in Table 5 and Table 6. The findings of first three questions were not included in the second survey to rate the opinions. Instead, the frequency of topics was calculated.

This study primarily aimed to seek information about possible mathematics topics for integration. Most of the experts preferred also to support his or her thoughts with science topics with some possible examples of ideas for integration (see Appendix D, E, and F, the results of which are summarized in English in Table 5 and Table 6). Therefore, given examples of topics in science were not ignored and the frequencies of topics were calculated. Table 5 and Table 6 were constructed by examining the responses and all examples and topics were categorized under common headings as numbers, functions, trigonometry, etc. The title of topics counted and frequency of the appropriate topics were calculated.

Topics for mathematics and physics integration

Derivative (f=16) was considered as the most common and popular topic in high school mathematics (Table 5).This topic was commonly combined with velocity and acceleration in physics which was probably why these topics mentioned most in physics (Table 6). Although integral is reverse of derivative, 12 experts gave integral as a common topic as well. Derivative was followed by trigonometry (f= 13). Trigonometric ratios and periodic functions were especially given as examples under the topic trigonometry and generally they were combined with optics, projectile motion, and force in experts' responses. More than half of the experts thought that trigonometry was a practical and suitable topic for M&P.

Table 5
Response frequency of mathematics topics for science integration

Mathematics and physics integration			
Derivative	16	Area	2
Trigonometry	13	Volume	2
Integral	12	Triangles	2
Functions [a]	7	Ratio and proportion[b]	2
Equations [c]	6	Matrices	2
Vectors	6	Geometry Of translation	1
Numbers[d]	5	Statistics	1
Limit	5	Periodic functions	1
Logarithm/Exponential func.	3	Differential equations	1
Analytical geometry of a line	3	Logic	1
Graphs	2	Coordinate plane	1
Complex numbers	2	Motion problems	1
Inequality	2		
Mathematics and chemistry integration			
Ratio and Proportion	12	Units	1
Logarithms/ Exponential func.	12	Angles	1
Numbers	10	Measurements	1
Equations	6	Inequality	1
Derivative	3	Statistics	1
Graphs	3	Operations	1
Geometry in 3-D	3	Integral	1
Function	2	Analytical geometry for lines	1
Polar coordinates	1	Logic	1
Mathematics and biology integration			
Probability	13	Function	2
Logarithm/Exponential func.	10	Permutation	1
Statistics	9	Ratio and proportion	1
Derivative	5	Units	1
Numbers	5	Scientific form	1
Graphs	4	Operations	1
Equations	3	Integral	1
Sets	2	Logic	1
Combination	2	Series	1
Percentage calculation	2		

[a]Functions: 1st and 2nd degree functions;[b]Ratio and proportion: mixture problems; Equations: 1st and 2nd degree equations;[d]Numbers: exponential numbers, square roots, very small and very large numbers, types of numbers

Table 6

Response frequency of science topics for mathematics integration

Physics integration		Chemistry integration	
Velocity	12	Mixture	7
Acceleration	11	Chemical reactions	5
Force	5	Acid-Base	5
Projectile motion	5	Radioactivity	4
Motion	5	Organic chemistry[c]	3
Optics	5	Compounds[d]	3
Free Fall	4	Experiments[e]	2
Mechanics	3	Heat in chemical reactions [f]	2
Work	2	Oxidation	1
Circuits	2	Avogadro number	1
Electric	2	Physic-chemistry	1
Heat	2	Volume	1
Vectors	2	**Biology integration**	
Kinetic energy	1	Genetic[a]	11
Harmonic motion	1	Population[b]	9
Angular velocity	1	Segmentation	3
Pressure	1	Experiments	2
Simple machine	1	Properties of creatures	1
Kinematics	1	Dose of medicine	1
Moment	1	Radiocarbon dating	1
Magnetic	1	Pollution	1
Waves	1	Recovery time	1
Sound intensity	1	Rate of growth	1
Mechanics of quantum	1		

Note.[a]Genetic;pedigree tree, dna graph, Mendel-cross breeding.[b]Population; increase or decrease in the amount of bacteria, number of people, reproductivity. [c]Organic chemistry; structures of molecules, angles between chemical bonds. [d]Compounds; ratio and proportion, distance between atoms. [e]Experiments; representation of results. [f]Heat in chemical reactions; Hess principle

Functions (*f*= 7), equations (6), vectors (6), numbers (5), limit (5), logarithm and exponential functions (3), and analytic geometry for line (3) were also considered suitable topics by the participants together with derivative, integral, and trigonometry (Table 5).Graphs, complex numbers, inequalities, triangles, area, volume, ratio-proportion, matrices, geometry of translation, statistics, periodic functions, differential equations, logic, coordinate planes, and motion problems were also considered as topics for this kind of integration by one or two experts.

Topics for mathematics and chemistry integration

Ratio and proportion (*f*=12), logarithms and exponential functions (12) were considered as the most common and popular topics in high school mathematics (Table 5).In the responses, ratio and proportion were commonly associated with mixture problems, compounds and equilibrium in chemical reactions in chemistry. Also, logarithms and exponential functions were considered together with ph-measurements and radioactivity. This is why; these topics, mixture, chemical reactions, acid-base and radioactivity were considered as appropriate topics of integration with chemistry (Table 6).

Ratio-proportion and logarithms-exponential functions were suggested next in frequency (*f* = 10). Especially, exponential numbers, radical numbers, numbers in scientific notation were given as examples and mostly, they were associated with chemical reactions, Avogadro numbers, compounds and mixtures. In addition to the topics given earlier, equations (6), derivative (3), graphs (3), and 3-D geometry (3) were considered as suitable topics by the academics and teachers (Table 5).Moreover, functions, polar coordinates, units, angles, measurements, inequalities, statistics, operations, analytic geometry for line and logic were given sample topics by fewer experts.

Topics for mathematics and biology integration

Probability (*f*=13) was considered as the most common and popular topic in high school mathematics for integration in biology. In the responses, probability was commonly associated with genetics in biology. Which may be why, genetics were considered the most common topic in biology (Table 6).Probability was followed by logarithms and exponential functions (10). Especially, logarithmic and exponential functions and their graphs were associated with the increase or decrease in population. Statistics (9) was also another common response for genetics in biology.

Derivative (5), numbers (5), graphs (4), equations (3) were offered as suitable topics by the academics and teachers in addition to probability, logarithm, and statistics. Moreover, sets, combination, percentage calculation, functions, permutation, proportion, units, scientific form, operations, integral, logic, and series were given by fewer participants (Table 5).

Chi-square test

For mathematics and physics integration, 25 topics in mathematics and 24 topics in physics were illustrated as suitable topics. For mathematics and chemistry integration, 18 topics in mathematics and 12 topics in chemistry were considered as suitable topics. For mathematics and biology integration, 19 topics in mathematics and 10 topics in biology were offered as appropriate topics (Table 5 and Table 6). The Chi-square test was used to determine whether there was a significant difference between the expected frequencies and the observed frequencies of the topics in physics, chemistry and biology. According to the results of the test given as Figure 3, topics for the integration in each of the three discipline were not equally distributed in the population, X^2 (2) = 7.48, $p< .05$.Physics had more topics that were suitable for mathematics integration than biology and chemistry topics.

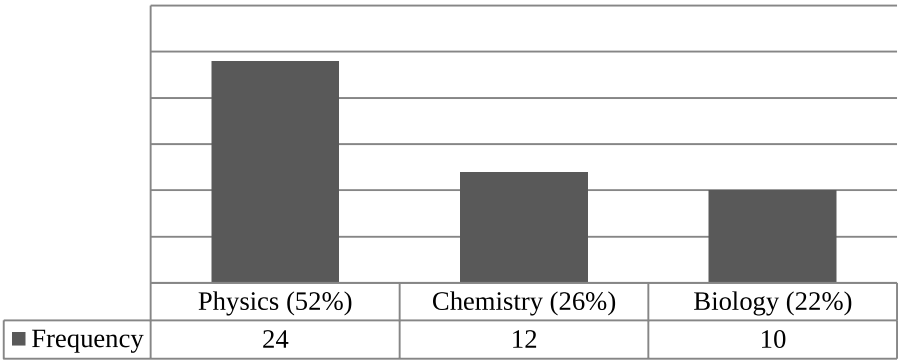


Figure 3.Graphs of distribution of science topics for mathematic integration (N=46, $\chi^2(2)$= 7,48, p<.05)

In addition to comparison of the distribution among topics in different science subjects, the commonality of topics in mathematics for physics, chemistry, and biology integration was analyzed. According to experts' opinion, derivative and integral, functions, equations, numbers, logarithms and exponential functions, graphs, ratio and proportion, statistics and logic were suggested for physics, chemistry, and biology integration. These topics in mathematics were considered as adaptable for each branch of science integration.

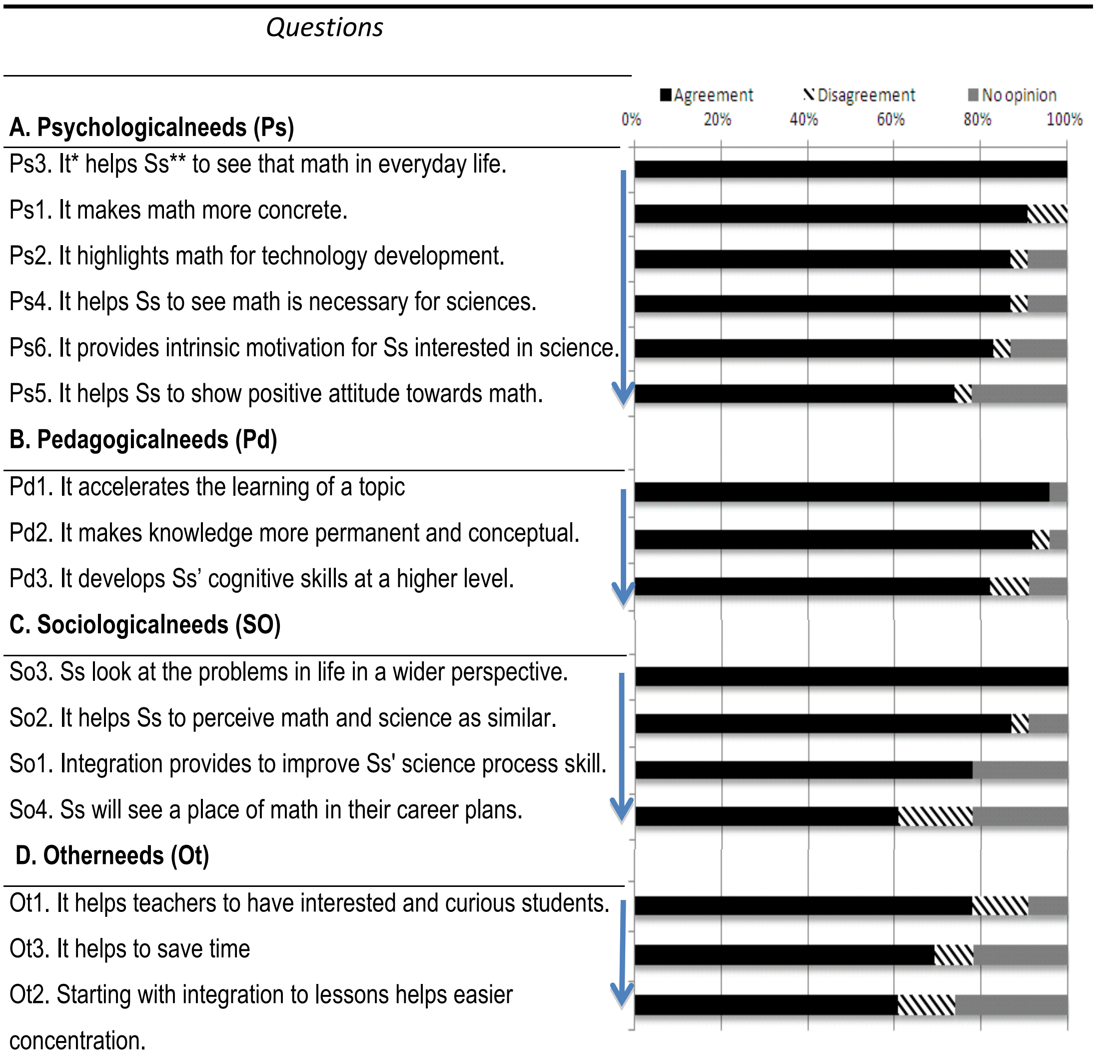
Degree of consensus on advantages

After collecting first round data, all experts rated the second round Likert scale. According to responses, Figure 4 was constructed to illustrate the degree of agreement and disagreement. In the Likert scale, 16 opinions about advantages of mathematics and science integration took place and there were 4 categories for opinions: psychological needs (Ps), pedagogical needs (Pd), sociological needs (SO), and other needs (Ot) that contained opinions that did not fit the first three needs. The first six opinions were analyzed under Ps; the next three opinions were analyzed under Pd; the next four opinions were analyzed under SO and the rest of the opinions were analyzed under Ot.

Experts reached a consensus with the items Ps3, each expert believed that integration provides students to see how mathematics is used in everyday life. In the responses (see Appendix G), they supported this idea by saying that it was easier to make real life connections with science rather than mathematics therefore integration provides students to see the place of mathematics in real life. The overwhelming majority of participants (91%) agreed with the idea, Ps1. Similar explanations for Ps3 were given for Ps1, integration makes mathematics more concrete. They believed that science topics make mathematics more concrete in students' minds cognitively.

So3 is another opinion that all participants reached a consensus on that integration helps students realize the importance of integration by the way they look at the problems in real life with a wider perspective. Moreover, there was strong agreement with the items in Pd1 (96%) which suggested that integration accelerates the learning of a topic with the help of discussions in more than one course. In addition to this advantage, the great majority of experts agreed that information is recorded within a network in students' minds cognitively (91%).

Most of the participants in this study agreed that students saw the place of mathematics in the development of technological tools (87%) and also integration allowed them to see mathematics as a necessary language for all sciences (87%). Moreover, 87% of the experts in this study supported the item Pd2; integration affects students' perception of similar concepts. They thought that their perceptions of similar concepts in mathematics and science as different topics were minimized.

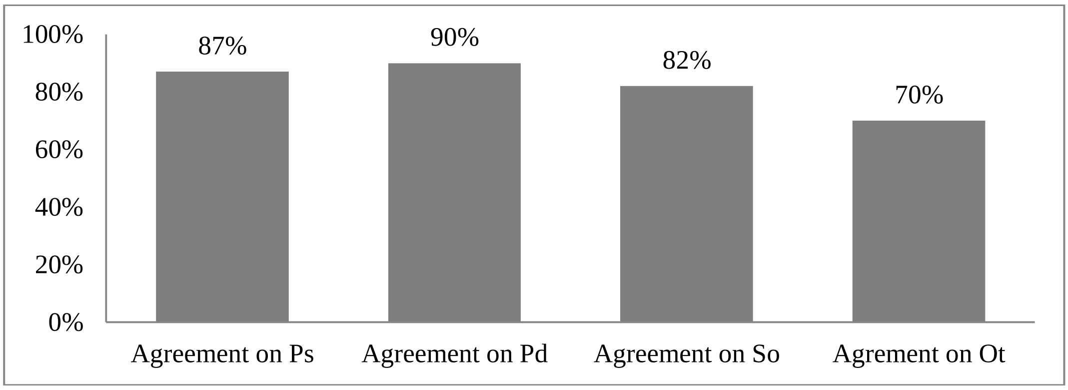


Note. *Integration, **Students.

Figure 4.Degree of consensus on the advantages of CIMAS

The great majority of experts agreed that integration allows students to develop positive attitudes toward mathematics (74%) and an intrinsic motivation for students who are especially interested in science (83%). There is strong agreement that it develops students' higher level cognitive skills (analyze, synthesize, and interpret) (83%) and science process skills (strategy development, independent thinking, the use of scientific language, etc) (78%). Also the majority of participants agreed on the idea of a relationship in the career plans of students and integrated curriculum. They agreed that students could see the place of mathematics in their career plans as an advantage of integrated curriculum (61%).

The experts thought that integration had advantages not only for students but also for teachers. The participants agreed that integration helps teachers in the implementation process of the course with interested and curious students (78%) and it also provides to save time by not discussing same or similar topics over and over again in both mathematics and science lessons (70%). Additionally, some experts shared their opinions about the sequence of lessons; the majority of participants agreed that examples of integration which are given at the beginning of the subject enable to get students' attention easier (61%).



Note. Ps, psychological needs; Pd, pedagogical needs; SO, sociological needs; Ot, other needs

Figure 5.Distribution of consensus among the categories

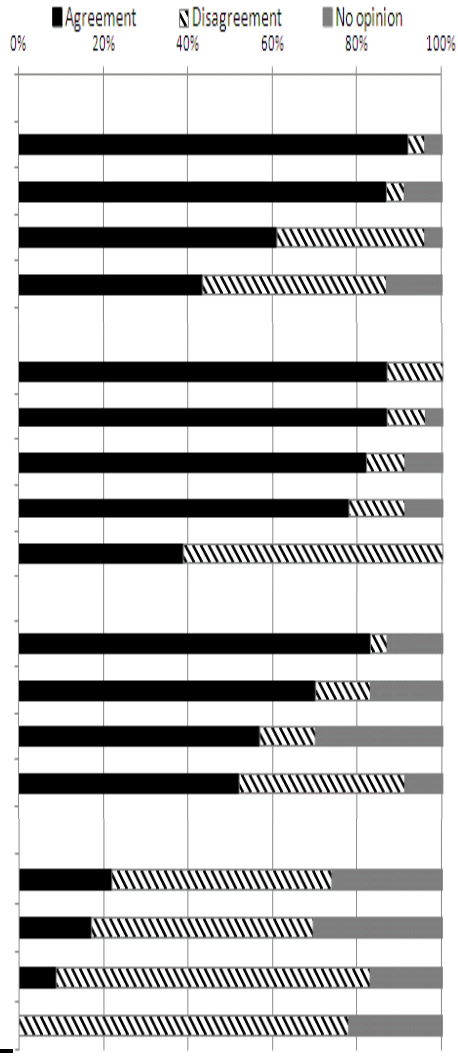
After the degree of agreements were calculated, also the mean of agreements for the categories Ps, Pd, SO and Ot were analyzed and they are given in the Figure 5. According to findings, the overwhelming majority of experts agreed that the integration of mathematics and science provides advantages in terms of Ps (87%), Pd (90%), and SO (82%).

Degrees of consensus on disadvantages and limitations

In this study, in addition to the advantages of the integration of mathematics and science, the disadvantages and limitations were also researched. Similar to the first 16 opinions about advantages, 17 opinions about disadvantages and limitations were placed in the Likert scale and they were categorized under four different categories constraints related to curriculum (Cc), constraints related to teachers (Ct), constraints related to students (Cs), and constraints related to facilities (Cf). Figure 6 was constructed to illustrate the degree of agreement and disagreement on constraints in the Turkish context. The first four opinions were analyzed under Cc, the next five opinions were analyzed under Ct, the next four opinions were analyzed under Cs and the last four questions were analyzed under Cf.

The overwhelming majority of the participants agreed that integration leads to loss of time if it is planned without a holistic view (91%) and also if mathematics and science topics don't synchronize, there will be trouble during the integration process (87%). Moreover, most of the experts agreed that the lack of communication between teachers prevents the integration from occurring in a healthy way (87%). Other opinions about the role of the teachers which had strong agreement are that teachers who don't have a deep knowledge in science can cause lots of confusion (87%) and reluctance of teachers because activities required time and effort created limitation for the integration (83%). The majority of participants agreed that mathematics teacher training programs which do not give enough place to science makes integration difficult (78%).

Questions
Constraints related curriculum (Cc)
Cc3. Integration leads to the loss of a lot of time.
Cc2. Unsynchronized curricula may cause problems.
Cc4. New additions increase the rush to finish the topics.
Cc1. Ts* and Ss** don’t find integration useful.
Constraints related teachers (Ct)
Ct2. Ts can create lots of confusion without correct links.
Ct3. Lack of communication among Ts damages integration.
Ct4. Reluctance of teacher creates limitation.
Ct1. Mttp*** doesn't give enough place for science courses.
Ct5. Math ideas are ignored because of more than one focus.
Constraints related to facilities (Cf)
Cf4. There are limited resources for integration.
Cf1. Integration is not possible for each topic.
Cf3. Unequal conditions in the country create challenges.
Cf2. It will be unfunctional without enough equipment.
Constraints related students (Cs)
Cs1. It causes Ss to show negative attitudes to math and sci.
Cs4. It prevents Ss to develop the ability to prove.
Cs3. It prevents Ss’ abstract thinking.
Cs2. It makes learning difficult.



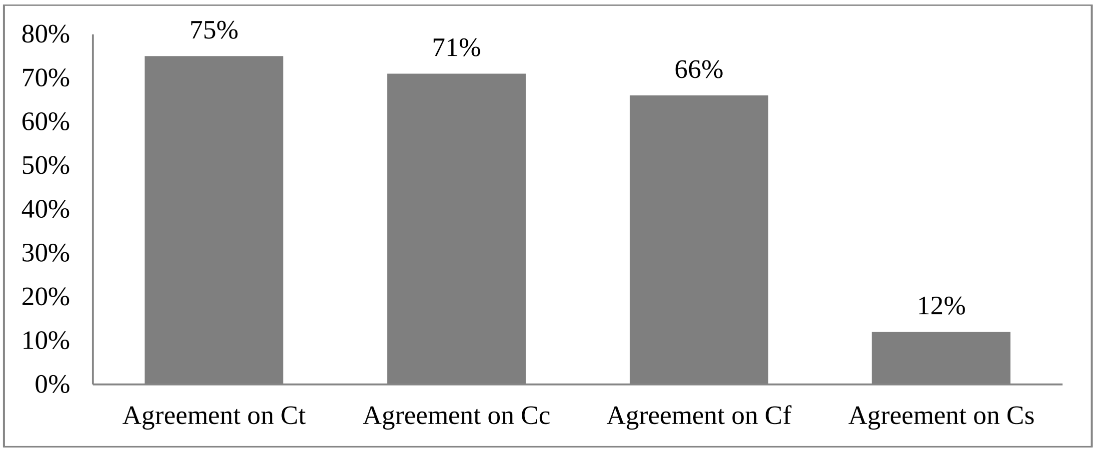
*Note.**Teachers, **Students, ***Mathematics teacher training programs.

Figure 6.Degree of the agreement on constraints in CIMAS

There was also strong agreement with the item Cf4, curriculum is not regulated for the integration therefore there are limited resources (83%) for teachers and students. Moreover, the great majority of participants agreed that integration was not possible for each topic in mathematics (70%). The majority of the experts agreed that a new addition to Turkish mathematics curriculum, which is already very dense, increases the rush to complete the topics (61%) although there were experts who disagreed (35%) with this opinion. Challenges in the integration process occur because of the different conditions all over the country was another opinion that the majority of experts agreed upon (57%). Almost half of the experts agreed that if there was not enough equipment (such as the use of technology) in the schools, it made integration nonfunctional (52%) while many of them (39%) disagreed with this idea.

The same number of experts (43%) agreed and disagreed that teachers don't find the integration useful since integration does not overlap with the format of university entrance exam. Although 39% of the experts agreed that mathematical ideas are ignored by putting science and real life situations to the focus of students instead of mathematics, the rest of them, 61% of experts, disagreed with this opinion. Moreover, only 22% of the participants agreed that integration causes students who don't like science or mathematics to exhibit negative attitudes towards other disciplines; on the other hand, almost half of the participants (52%) disagreed with this opinion. Similarly, number of people who disagreed with the item Ct4, the experimental method used in science causes students to think the method can be also used in mathematics to prove the theorems and so integration prevents to develop the ability to prove mathematical statements, was more than the number of people who agreed (17%).There was strong disagreement with item Cs3 which says integration prevents students' abstract thinking (74%). Only 9% of experts agreed with this opinion. Finally, great majority of participants disagreed with the item Cs2 integration attracts students' focuses to other points so it makes learning difficult (78%).

After the degree of agreements and disagreement were calculated among disadvantages and limitations, the mean of agreements for the categories Cc, Ct, Cs and Cf were analyzed and they are given in the following Figure 7. According to findings, the majority of experts agreed that integration of mathematics and science has disadvantages or limitations in terms of Ct (75%), Cc (71%), and Cf (66%). Few of them agreed on the disadvantages about Cs (12%).



Note. Cc, constraints related curriculum; Ct, constraints related teachers; Cs, Constraints related students; Cf, Constraints related facilities.

Figure 7.Distribution of agreement among categories

When the data about the disadvantages and limitations in Turkish context were analyzed, most of the responses related to limitations. From the 17 opinions in the Likert scale survey, six of them (Cc4, Ct5, Cs1, Cs2, Cs3, Cs4) mentioned the possible disadvantages and the rest of them mentioned the possible limitations during the implementation process. Table 7represents the mean of the degree of agreement among limitations and disadvantages. It indicates that participants mostly agreed on limitations of CIMAS more than the disadvantages of CIMAS.

Table 7
Distribution of agreement among limitations and disadvantages

Category	*Questions*	*Degree on agreement*
Limitations	Cc1,Cc2, Cc3, Ct1, Ct2, Ct3, Ct4, Cf1, Cf2, Cf3, Cf4,	74%
Disadvantages	Cc4, Ct5, Cs1, Cs2, Cs3, Cs4	25%

CHAPTER 5: DISCUSSION

Introduction

This study aimed to answer two research questions: ‘What could be the most appropriate topics in mathematics for curriculum integration of mathematics with science?’, and ‘What are the advantages, disadvantages and limitations of integration of science into mathematics?’. The discussion of the findings is organized according to following outline.

1. Mathematics and science topics for integration
2. The needs in CIMAS
3. Constraints of integration in CIMAS
4. Implications for practice
5. Implications for research

Discussion of the mathematics and science topics for integration

What could be the possible topics in mathematics for integration with science? Examples were categorized under each unit heading and counted. According to the frequency of the given examples for mathematics and science integration, the most common topics in mathematics are derivatives for mathematics and physics, ratio-proportion and logarithms-exponential functions for mathematics and chemistry, probability for mathematics and biology (Table 5). Moreover, some mathematics topics stood out for physics, chemistry, and biology integration. These common topics are derivative and integral, functions, equations, numbers, logarithms and exponential functions, graphs, ratio and proportion, statistics, and logic. The list of the topics would be beneficial for mathematics teachers to enrich their lessons by integration with the different branches of science.

The participants gave examples for each unit in all high school mathematics curriculum except for polynomials (Table 1and Table 5). Therefore, almost each unit in high school can combine at least one of the three branches of science by the help of activities, problems, examples although the great majority of participants (70%) agreed that integration was not possible for each topic (Figure 6). One inference for this argument could be that individually people are not capable on making integration for each topic in mathematics and with an effective cooperation; changes in the mathematics curriculum can be practiced successfully. This addresses the reason why teachers in schools must work cooperatively during the integration process for a successful integration program (Wicklein& Schell, 1995).

Appropriate science topics were analyzed in addition to mathematics topics. When the number of examples in each branch of science is calculated, the number of physics topics is significantly more than the number of topics in chemistry and number of topics in biology. Therefore, physics seems more feasible for integration.

Discussion of the needs in CIMAS

What will be the advantages, disadvantages, and limitations of integration of science into mathematics? The Delphi method was used to indicate the degree of agreement about advantages and disadvantages of integration of science into mathematics. First, the degree of agreement on advantages is discussed by considering psychological, pedagogical, sociological and other needs. There was not significant disagreement about advantages as elicited in the second Likert survey.

Psychological needs

According to the findings, the integration of science and mathematics allows students to see the place of mathematics in everyday life (Figure 4). This analysis can be supported with the idea: mathematics and science are complementary to each other and the integration of them is highly feasible and overlaps with the real world applications (Frykholm& Glasson, 2005). This is why the overwhelming majority of participants believe that integration makes mathematics more concrete and provides students the ability to see mathematics as a necessary tool for science. Therefore, it can be inferred that science allows mathematics to be more concrete and to be in relation with everyday life. In this light, integration helps students to find the answer of why they need to learn mathematics and where they will use it. Also, students in Turkey believe that giving information about these question would be beneficial and helpful for them (Costu, Arslan, Çatlioglu, &Birgin, 2009).

Since these kinds of questions are answered by the help of integration, expectedly, it increases the positive attitudes toward mathematics and provides intrinsic motivation especially to students who are interested in science according to the findings (Figure 4). Jacob’s (1989), Hoaclander’s (1999) , Klein’s (2005), Cosentino’s (2008) opinions have parallelism with the findings; integration of science and mathematics helps to increase real life examples and mathematics curriculum should be developed with the real life situations to increase students’ motivation and positive attitudes toward mathematics. These findings indicate that integration covers psychological needs of students that should be considered while developing curriculum. Since our Ministry of National Education aims to increase students' motivation in high school (MoNE, 2011), curriculum integration of mathematics and science is an effective tool to increase motivation and positive attitudes towards mathematics according to the findings of the study. In summary, the psychological needs can be presented in the flow list below:

Math&Sci integration→ increases real life connections in math → makes mathematics more concrete (e.g., usage in technological and scientific developments)→increases motivation & positive attitudes towards math

Pedagogical needs

A topic is discussed in mathematics or science and used in other courses. Such kind of review provides the integration of mathematics and science to support and accelerate the learning of the topic according the findings. Also this study shows that information takes place as a network in the mental processing more permanently and conceptually by the help of connections between the knowledge (Figure 4). Since, integration allows students to compare and contrast the ideas and to construct the connections from different views, it helps students to be better on complex problems (Klein, 2005, p. 10) and it helps to get higher scores in mathematics and science lessons (Cosentino, 2008, p. 72). Parallel with the findings, this study indicates that integration of science and mathematics develops students' higher level cognitive skills such as analyzing, synthesizing and interpreting (Figure 4). This findings can be supported by the idea that the integrated curriculum approach requires constructivist instruction instead of memorizing and following prescribed steps (Kaya et al., 2006; Klein, 2005; Loepp, 1999).

Meaningful learning is directly related with making connections and applying knowledge in a different idea (MoNE, 2011). In the light of these findings, CIMAS provides learning to be more permanent, conceptual and also more meaningful. These all indicate that integration covers essential pedagogical needs of students that should be considered while developing curriculum. Since our Ministry of National Education seeks meaningful learning (not only remembering or identifying the knowledge but also understanding the underlying meaning of it) (MoNE, 2011), curriculum integration of mathematics and science is an effective tool that leads to meaningful learning in keeping with the constructivist approach. In summary, the pedagogical needs can be presented in the flow list below:

Math&Sci integration → increases connections & applications → develops cognitive understanding and makes learning long-lasting, conceptual and meaningful →students' higher scores in mathematics

Sociological needs

This study found that integration helps students to approach problems in real life with a wider perspective. They can understand the importance of interdisciplinary studies. They may perceive science and mathematics as different disciplines however integration helps to minimize this perception (Figure 4).

Since we live in society, education should respond to the expectations of the society. In this information age, society expects us to solve complex problems.

Correspondingly, previous research indicates that the growth of knowledge requires the integration of knowledge in mathematics education as a requirement for this scientific age (Jacobs, 1989; Kaya et al., 2006).This study also indicates that integration of science and mathematics improve students' science process skills such as developing strategies, independent thinking, using scientific language etc. (Figure 4).

Our National Curriculum of Mathematics aims to allow students to realize the widespread area of usage of mathematics in real life and in the fields of their occupation. This goal makes educational attainments more meaningful (MoNE, 2011). Thanks to the integration of science and mathematics, the majority of participants agreed that students realize the place of mathematics in their career plans (Figure 4). In this way, students are aware of the mathematics usage in their occupation would be happy with their profession in the long run. In the light of the findings, CIMAS provides a response to the basic expectations of the society. These all indicate that integration covers essential sociological needs of societies that should be considered while developing curriculum. Curriculum integration of mathematics and science is an effective tool to move with the times. In summary, the sociological needs can be presented in the flow list below:

Math&Sci integration→solve the problems with wider perspective (such as minimization of difference between science and mathematics) and improve science process skills→ satisfies the necessities of the modern society

Other needs

The integration of science and mathematics also indicates important advantages for the teaching process of a course by setting interested and curious students, saving time, and taking their attention easily (Figure 4).Lonning's and DeFranco's (1997) study have parallelism with the findings of this study. They found that if some topics can be taught together, they will be more meaningful than if they were taught separately. By this way, integration helps to save time. In the light of these findings, during instruction, there are also important advantages of integration science and mathematics. Since curriculum should be developed by considering the learning objectives, instructional activities, assessment together, integration of mathematics and science can be accepted as one of the effective tools for the instructional process. In summary, the other needs can be presented in the flow list below:

Math&Sci integration→increases student curiosity→saves time & takes students' attention easier→ provides the effective environment for instruction

Discussion of the constraints of the integration in CIMAS

Although this study found that experts think that integration of mathematics and science should be used as an effective tool for the learning process, it also indicates that there are important constraints that should be considered during curriculum development process.

Limitations versus disadvantages

Responses from the second round Likert survey can be categorized into two parts; limitations that are obstacles of effective implementation of integrated curriculum and disadvantages that hinders the instruction and learning process. This study indicates low agreement (25%) for the disadvantages of curriculum integration, while showing higher agreement (75%) for the limitations. From the findings, it can be inferred that integration of mathematics and science did not have critical disadvantages that hinder the learning and teaching process. Rather the experts listed the constraints: curricula, teachers, facilities, and students.

Success in the implementation process of integrated curriculum is directly related to how much curriculum re-design is successful and innovative (Wicklein& Schell, 1995). Correspondingly, this study indicates that CIMAS leads loss of time if it is planned without holistic approach although the findings also indicate that it allows saving time for learning process. Unsynchronized curricula of mathematics and science are accepted as a critical problem that is mostly originated from the absence of a holistic approach (Figure 4&Figure 5). Therefore, it can be inferred that the absence of a holistic approach can be the most important limitation in curriculum design. Such kind of coordination should be considered with the context of not only curricula but also the teachers and administration (Wicklein& Schell, 1995).

Lack of communication between teachers is another important constraint during the implementation process of CIMAS (Figure 5). This result is consistent with the previous results, teachers and administration's effective collaboration to design an integrated curriculum is an essential factor. Lack of teacher coordination of curricular content causes important problems (Wicklein& Schell, 1995). The concerns about the communication and holistic approach can be combined under the planning process of integrated curriculum and so it can be easily understood that planning has a significant role in developing an integrated curriculum.

Moreover, in the context of constraints related to teachers, this study indicates the importance of additional background knowledge to communication between teachers. Mathematics teacher training programs are not sufficient in terms of teaching science. For this reason, teachers who may not have deep knowledge on science can lead to confusion (Figure 5). Correspondingly, teachers' background knowledge of the commonalities between mathematics and science placed significant constraints in previous research. Although experienced teachers believed they had more background knowledge than pre-service teachers, still the great amount of experienced teachers that felt they had sufficient knowledge is not enough (Lehman, 1994). As this study indicates teacher training programs do not give enough importance to science and mathematics integration in Turkey. Since the importance of integrating knowledge increases day by day in a globalized world, universities need to revise teacher training programs(Balay, 2004) and the teachers need to be experienced over multiple subjects (Loepp, 1999).

This study also found that there exist limited resource that can be used by teachers and students, since curriculum is not regulated according to mathematics and science integration. Planning lessons in the light of integrated knowledge demands more responsible collaboration, effort, and time (Wicklein& Schell, 1995).Reluctance of teachers can create another limitation for integration process in the schools as it is found in this study. Moreover, for integration, this study indicates that there is no critical prerequisite needed in terms of extra facilities such as technology although these facilities can ease and enrich the integration (Figure 5).

This study indicates that there are no critical constraints related to the students' learning process. Although some previous research indicates that integration may cause limited learning (Wicklein & Schell, 1995) and students may have difficulties to catch important points in the lessons (Cosentino, 2008), this study does not point significant agreement about these constraints. Integration does not make learning difficult, does not prevent student's abstract thinking or ability to prove, and does not cause negative attitudes toward mathematics according to experts.

Implication for practice

In the Turkish context, there have been reported significant limitations in mathematics education. The findings emphasize the importance of planning an integrated curriculum, improving teacher training programs, and developing sources for integration. For effective implementation, these barriers can be eliminated with careful planning to improve current situations.

Mathematics curriculum can be developed using topics and examples of integration. While developing curriculum for science into mathematics integration, the synchronization between science and mathematics curriculum should be ensured. By this way, repetitions or reminders can be minimized and so integration helps to save time. This is why such kind of mathematics curriculum must be redesigned with the collaboration of mathematics curriculum developers and science curriculum developers.

Although the curriculum can be redesigned with the collaboration of both science and mathematics curriculum developers, it may not produce sufficient collaboration for the implementation process of this curriculum. Teachers' collaboration is also essential because the lack of communication between teachers prevents effective integration. At this point, administrators should take an important role and organize regular meetings between teachers from different disciplines. Since there are limited resources about integration, administrators must provide support for teachers. For this purpose, professional meetings can be organized and teachers should be encouraged to attend conferences on the topic.

One of the significant limitations of integration is the background information of teachers since mathematics teacher training programs do not give enough importance to science and mathematics integration. Therefore, teacher educators must inform pre-service teachers about implementation process of integration in their methodology classes. Possible topics, advantages, and constraints should be discussed and they should be encouraged to plan interdisciplinary units with the collaboration of their peers.

Implication for research

This study presents the perceptions of experts who are teachers and academics in education faculties about the implementation process of integrated mathematics and science curriculum. Since the commonality of perceptions of experts is presented without any comparison between teachers and academics in this study, further research could focus on the differences on how teachers and academics perceive science and mathematics integration. Comparison of theoretical perception of academics and practical perception of teachers about integration may be resulted with valuable findings. Moreover, pre-service teachers' opinions can be added to this comparison. Background knowledge about the integration of experienced and pre-service teachers can be compared. Comparisons of pre-service and experienced teachers' opinions may indicate some implications for improvement of teacher training programs.

The topics, which are appropriate for mathematics and science, can be also analyzed with the collaborative work of mathematicians and scientists. New units can be constructed and implemented with an experimental study to test the ideas in this study. Such a study would present the practical consequences of integrated curriculum as opposed to the theoretical consequences of integration of mathematics and science.

Due to their commonality of addressing conceptual understanding, it has been regarded as being feasible to integrate mathematics and science. In order to satisfy social needs, however, further researches should be carried out to explore opinions about the features of implementation process of integrated curriculum between mathematics and the social studies. Possible topics could be appropriate in mathematics for the social sciences integration can also be researched. The results of such a study would be valuable for curriculum developers, teachers, and administrators.

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APPENDICES

APPENDIX A: Cover letter for the first round survey

Mr «TITLE» «NAME» «SURNAME»,

As a graduate student in Bilkent University, Institute of Education Sciences, I am planning to collect experts' opinion about my thesis topic, "Integration of High School Mathematics and Science Curriculum ". I would like to request you to attend my survey with your valuable and useful knowledge in mathematics education.

The first round survey consists of open-ended questions on the link given below. It will take approximately 15-20 minutes to answer.

As a continuation of this stage, Likert-type questionnaire will be prepared in the lights of answers given at the first round and you will be asked to rate this. It will take again approximately 15 minutes to answer. In Delphi technique, second survey can be sent only the participant who participated to previous round. Therefore, the continuity of participation to surveys is very important.

Moreover, the exact identities of the participants will be kept confidential.
Please fill out the questionnaire for the continuation of the study within 5 days.
Thank you in advance for your participation and support.

This study has necessary permission for the Ankara Provincial Directorate of National Education. If you have questions, you can contact me or my supervisor with e-mail.

Click here for survey: http://t4.ed.or.kr

Sincerely yours,

Tugba Aktan (aktan@bilkent.edu.tr)
Masters in Curriculum and Instruction with Teaching Certificate in Mathematics
Asst. Prof. Dr. Minkee Kim (Supervisior; minkee@bilkent.edu.tr)

APPENDIX B: The first round open-ended questions

1. Which topics in mathematics high school curriculum can be considered as appropriate for mathematics and physics integration? Please explain it with examples.

2. Which topics in mathematics high school curriculum can be considered as appropriate for mathematics and chemistry integration? Please explain it with examples.

3. Which topics in mathematics high school curriculum can be considered as appropriate for mathematics and biology integration? Please explain it with examples.

4. What could be the possible advantages of integration of science to mathematics for students' learning process? Please explain your opinions with examples.

5. In Turkish context, what could be the possible disadvantages and limitations of science to mathematics that affect students' learning process? Please explain your opinions with examples.

APPENDIX C: Screen shot of the online first round survey

Bu anketin cevaplanması yaklaşık 15-20 dakikanızı alacaktır. Yanında yıldız işareti olan soruların cevaplanması gerekli olup, gerekli bütün alanlar doldurulduktan sonra formun gönderilmesi mümkündür.

Lise Müfredatında Matematik ve Fen Bilimlerinin Entegrasyonu

Bu ankette amaç, psikolojik, pedagojik ve sosyolojik faktörler göz önünde bulundurularak, Türkiye koşulları çerçevesinde, lise matematik müfredatına fen bilimleri entegrasyonun avantajları ve dezavantajları konusunda bir fikir birliğine varmaktır. Buna ek olarak söz konusu görüşler doğrultusunda, entegrasyona uygun matematik konularını belirlemek amaçlardan bir diğeridir.

Tuğba Aktan
Dr. Minkee Kim (Danışman)
Eğitim Bilimleri Enstitüsü
Bilkent Üniversitesi

* Required

İsim, Soyisim

Lise Müfredatında Matematik ve Fen Bilimlerinin Entegrasyonu

Bilim ve teknolojideki gelişmeler, içinde yaşadığımız bilgi çağıyla bir paralellik kurması açısından, matematik ve fen eğitiminin önemini artırmaktadır. Bu bağlamda matematik ve fen konularının entegrasyonunun müfredata yansıtılması tartışılan bir konudur.

Entegrasyon değişik şekillerde gerçekleştirilebilmektedir. Aşağıdaki sorularda bahsi geçen entegrasyon, matematiği merkeze koyarak fen bilimlerinden yardım almayı amaçlamıştır. Matematikteki konulara ve ya problemlere farklı açılardan yaklaşmayı ve fen bilimlerinden yardım almayı amaçlayan bu yaklaşım, matematik için fen bilimleri entegrasyonu olarak adlandırılmıştır.

A01a. Hangi lise matematik konuları fizik entegrasyonuna uygun olarak düşünülebilir? Lütfen örneklerle açıklayınız. *

A02a. Hangi lise matematik konuları kimya entegrasyonuna uygun olarak düşünülebilir? Lütfen örneklerle açıklayınız. *

APPENDIX D: Responses for the first open-ended question

The results of the table below were summarized in Table 5 and Table 6.

Participant	Responses	Topics in Mathematics	Topics in Physics
1	Aklıma ilk gelen Trigonometri ve serbest atışlar oldu. Veya Türev ile İntegral hız-zaman, ivme-zaman grafikleri ile ilişkilendirilebilir. Yol-zaman grafiğindeki eğim hızı verir gibi veya hız zaman grafiğin altındaki alanın yol vermesi gibi...	•Trigonometri (Trigonometry) •Türev (Derivative) •İntegral (Integral)	•Serbest atış (Projectile motion) •Hız (Velocity) •İvme (Acceleration)
2	Eşitsizlik, denklemler, karekök, mutlak değer, üslü ifadeler, fonksiyonlar, trigonometri. Bunlar aklıma gelenler, temel ilgi alanım lise matematiği olmadığı için çok ilgilenmiyorum ve size de örnek veremiyorum.	•Eşitsizlikler (Inequalities), •Denklemler (Equations), •Karekök (Root numbers), •Üslü ifadeler (Exponential expressions), •Mutlak değer (Absolute value) , •Fonksiyonlar (Functions), •Trigonometri (Trigonometry)	
3	Konular: Cebir, vektörler, koordinat sistemleri, fonksiyon, grafik, ikinci dereceden denklemler, Üslü sayılar (Exponential numbers) ve temel dik üçgen trigonometrisi, trigonometri, limit, türev, integral Fen bilimleri arasında, lise düzeyi dikkate alındığında, en çok "fizik dersinde matematiğe gereksinim duyulduğu kaçınılmazdır. Fizikte, hız, ivme, iş, kuvvet ve daha birçok konuda matematiğe gereksinim duyulacağı söylenilebilir.	•Cebir (Algebra), •Vektörler (Vectors), •Koordinat sistemleri (Coordinate systems), •Fonksiyonlar (Functions), •Grafik (Graphs), •İkinci dereceden denklemler (Second degree equations), •Üslü sayılar (Exponential numbers) •Trigonometri (Trigonometry), •Limit (Limit), •Türev	•Hız (Velocity) •İvme (Acceleration) •İş (Work) •Kuvvet (Force)

		(Derivative), •İntegral (Integral)	
4	Mantık (devre tasarımı) Trigonometri (birçok fiziksel durum trigonometrik bağıntılar içerebilmekte. Bu çerçevede öğrenilen konuların günlük hayat bağlamında nerede nasıl kullanılacağından bahsetmek bile önemli olabilir.) Karmaşık sayılar (karmaşık sayılar, eşlenik vb. kavramlar fizikte elektrik konularında kullanılmakta.) Limit-Türev-Integral (anlık hız vb. hareket ve atışla ilgili fizik konuları ile çok kolay ilişkilendirilebilir. Bu bağlamdaki grafikler--hız-zaman, konum-zaman okuma ve bunlarla ilgili çıkarımda bulunma ilişkileri kurulabilir) İkinci dereceden denklem ve fonksiyonlar (parabolik path ler fizikte önemli bir yere sahip Eğik atış, serbest düşme vb. olaylarla ilgili problemler çoğu zaman ikinci dereceden denklem ve fonksiyonları içeriyor.)	•Mantık (Logic) •Trigonometri (Trigonometry) •Karmaşık sayılar (Complex numbers) •İkinci dereceden denklemler (Second degree equations) •İkinci dereceden fonksiyonlar (Second degree functions) •Limit (Limit) •Türev (Derivative) •İntegral (Integral)	•Devre tasarımı (Design of circuits) •Elektrik (Electrics) •Hız (Velocity) •Eğik atış (Projectile motion) •Serbest düşme (Free fall)
5	Türev, integral ve bunlara bağlı konular. Fizikte (elektrik, mekanik, vb.) Pre-calculus konuları da bu çerçevede düşünülebilir.	•Türev (Derivative) •İntegral (Integral)	•Elektrik (Electrics) •Mekanik (Mechanics)
6	Türev: Hareket, ısı değişimi konuları ile ilişkilendirilerek 2. dereceden denklemler: Serbest düşme, kinetik enerji konuları ile ilişkilendirilerek Fonksiyonlar ve grafikleri: hız-zaman-ivme konuları, sarkacın periyodunun bulunması, basit harmonik hareket konuları ile ilişkilendirilerek Basit trigonometrik eşitlikler: Kuvvet konusu, açısal hız konusu ile ilişkilendirilerek Sayılar (üslü-köklü sayılar, oran-orantı,): Kuvvet, basınç, kaldıraçta denge oluşturma, ısı ölçü birimleri arasında dönüşüm.	•Türev (Derivative) •İkinci dereceden denklemler (Second degree equations) •Fonksiyonlar (Functions) •Trigonometri (Trigonometry) •Sayılar (üslü-köklü) •Oran-orantı (Ratio-proportion) •Eşitsizlikler (Inequalities)	•Hareket (Motion) •Isı değişimi (Heat) •Serbest düşme (Free fall) •Kinetik enerji (Kinetic energy) •Hız (Velocity) •İvme (Acceleration) •Basit harmonik hareket (Harmonic motion) •Kuvvet (Force) •Açısal hız (Angular velocity) •Basınç (Pressure) •Kaldıraç (Simple machine) •Isı dönüşümleri (Heat in chemical

	Eşitsizlikler		reactions)
7	Fizik bilimini doğanın matematikle tanımlanması olarak kabul edersek hemen hemen her konu entegrasyona uygun olabilir. Newton'un türev ve integrali sırf klasik mekaniği geliştirmek için keşfettiğini düşünürsek lise kinematik konularıyla entegre edilebilirler. Optikte birçok yerde trigonometri kullanılır. Logaritma ve üslü fonksiyonlar yarı ömür konularıyla entegre edilebilir. Geometri de birçok fizik konusuyla (optik, kuvvet, moment...) entegre edilebilir. Deneysel çalışmalara istatistik iyi bir şekilde entegre edilebilir. Alan ve hacim konuları fizikte kullanıldığından entegrasyon için uygun olabilir.	•Türev (Derivative) •İntegral (Integral) •Trigonometri (Trigonometry) •Logaritma (Logarithm) •Üstel fonksiyon (Exponential function) •Geometri (Geometry) •İstatistik (Statistics) •Alan (Area) •Hacim (Volume)	•Kinematik (Kinematics) •Optik (Optics) •Kuvvet (Force) •Moment (Moment)
8	Tüm sayısal işlem becerileri (dört işlem, kesirli sayılar, oran-orantı, ondalıklı sayılar, köklü ve üslü sayılar, …). Trigonometri, türev, vektörler, hacim hesaplama, karmaşık sayılar, diferansiyel denklemler, matrisler gibi konular fizik derslerinde aktif olarak kullanılmaktadır.	•Sayılar (Numbers) •Oran-orantı (Ratio-proportion) •Trigonometri (Trigonometry), •Türev (Derivative), •Vektörler (Vectors), •Hacim (Volume), •Karmaşık sayılar (Complex numbers), •Diferansiyel denklemler (Differential equations), •Matrisler (Matrices)	
9	Türev ve integral konusu ile fizik entegrasyonu düşünülebilir. Bunun yanı sıra fiziğin pek çok konusunda matematiksel metotlara ihtiyaç olduğundan matemtiksiz fizik düşünülemez.	•Türev (Derivative) •İntegral (Integral)	
10	Vektörler, yansıma-simetri ve hareket problemleri örnek olarak verilebilir.	•Vektörler (Vectors) •Yansıma (Reflection) •Simetri (Symmetry) •Hareket problemleri (Motion problems)	•Vektörler (Vectors)

11	1) Türev ve İntegral konuları, fizikteki hareket ve manyetik konularına entegre edilebilir. Örnek: Fizikteki yol-zaman grafiklerinde 1. türevin hızı 2. türevin ise ivmeyi vermesi. Ayrıca hız-zaman grafiğinde grafiğin altında kalan alanın yolu vermesi gibi. 2) Geometrideki vektörler konusunun da Fizikte kuvvetlerle ilgili konularda uygulaması olabilir. 3) Trigonometrik oranların Fizikteki Optik konusunda çok fazla uygulaması var, ışığın kırılmasıyla ilgili. 4) Analitik Geometrideki doğru grafiklerinin Fizikteki benzer grafikleri açıklamaya yardım etmesi mümkün.	•Vektörler (Vectors) •Türev (Derivative) •İntegral (Integral) •Trigonometri (Trigonometry) •Analitik geometri (Analytic geometry)	•Hareket (Motion) •Manyetik (Magnetics) •Hız (Velocity) •İvme (Acceleration) •Kuvvet (Force) •Optik (Optics)
12	Hız problemleri, Türev	•Türev (Derivative)	
13	İkinci Dereceden Fonksiyon ve Parabol konusunun eğik ve yatay atış konularına göndermeler yapılarak anlatılabileceğine düşünüyorum. Eğik ve yatay atış hareket formüllerinin ikinci dereceden olması, eğik atışı şekilsel ifade ettiğimizde parabole benziyor oluşu kullanılabilir diye düşünüyorum. Lineer fonksiyonlar ve grafikleri konusunda, düzgün doğrusal hareket için konumun zamana bağlı değişimi örnek olarak verilebilir. Yine hareket konusunu düşünürsek eğer, türev konusunda ani ivme ve ani hız hesaplamalarının kullanıldığı gösterilebilir. Bunların dışında geometride vektörler konusu da fizikteki kuvvet konusuna göndermeler yapılarak işlenebilir. Trigonometri konusunda periyodik fonksiyonlar işlenirken fizikteki dalgalar ve periyotları kavramlarına vurgu yapılabilir.	•İkinci dereceden fonksiyonlar (Second degree functions) •Lineer fonksiyonlar (Linear Functions) •Grafik (Graphs) •Türev (Derivative) •Trigonometri (Trigonometry) •Periyodik fonksiyonlar (Periodic functions) •Vektörler (Vectors)	•Eğik atış (Projectile motion) •Hareket (Motion) •Kuvvet (Force) •Dalgalar (Waves) •Hız (Velocity) •İvme (Acceleration)
14	Vektörler, trigonometri, ondalık sayılar, reel sayılar, üslü sayılar, 1. ve 2. dereceden denklemler	•Vektörler (Vectors), •Trigonometri (Trigonometry), •Sayılar (Numbers), •1. dereceden denklemler (First degree equations) •2. dereceden denklemler (Second degree equations)	
15	Fonksiyonlar, trigonometri, limit, türev,	•Fonksiyonlar	

	integral örnek sinis cosinüs grafikleri integralde alan parçaçıkları.	(Functions) •Trigonometri (Trigonometry), •Limit (Limit), •Türev (Derivative), •İntegral (Integral)	
16	Trigonometri, türev, integral, eğim hesaplama, hız, ivme bulma	•Trigonometri (Trigonometry), •Türev (Derivative), •İntegral (Integral)	•Hız (Velocity) •İvme (Acceleration)
17	-Türev konusunda fizikteki mekanik (yolun zamana göre türevi hızdır -Limit, optik kosunda -Integral, fizikteki iş, mekanik konuları	•Limit (Limit) •Türev (Derivative) •İntegral (Integral)	•Mekanik (Mechanics) •Hız (Velocity) •Optik (Optics) •İş (Work)
18	İkinci derece denklemler konusu özellike atışlar ve ivmeli hareketler başlıklarıyla zenginleştirilebilir.	•2. Dereceden denklemler (Second degree equations)	•Atışlar (Projectile motion, free fall) •İvme (Acceleration) •Hareket (Motion)
19	Türev ve integral, vektörler örneğin hız problemlerinde hızın türevinin ivmeyi, ivmenin integralinin hızı vermesi. Hız ivme ve konum vektörleri.	•Türev (Derivative) •İntegral (Integral)	•Vektörler (Vectors) •Hız (Velocity) •İvme (Acceleration)
20	Doğrunun analitiği: yer, yol, hız, ivme grafikleri, doğru ve ters orantılı değerler 2. dereceli denklem ve fonksiyonlar: eğik atış, serbest düşme Trigonometri: grafik hesaplamalarında Logaritma-Üstel Fonksiyonlar: hesaplamalarda Limit, türev, integral: mekanik problemlerinde	•Limit(Limit) •Türev (Derivative) •İntegral (Integral) •Doğrunun analitiği (Analytic geometry for lines) •Trigonometri (Trigonometry) •Logaritma (Logarithm)-Üstel fonksiyon (Exponential function)	•Hız (Velocity)-İvme (Acceleration) •Eğik atış (Projectile motion) •Serbest düşme (Free fall) •Mekanik (Mechanics)
21	-Optik bir fizik konusudur. Üçgenle ilgili benzerlik, öklit, dik üçgen özellikleri kullanılır. -y=ax+b, a and b are elements of R doğrusal bir fonksiyondur. Bunu fizikte düzgün doğrusal hareket olarak kullanıyorlar. Yol, hız, zaman ilişkisini bu fonksiyonlarla açıklıyorlar. (iki fiziksel değişkenin birbirine göre durumları) -türev konusu fizikte hız ve ivme hesaplarında	•Üçgenler (Triangles) •Lineer fonksiyonlar (Linear Functions) •Türev (Derivative) •İntegral (Integral)	•Optik (Optics) •Hareket (Motion) •Hız (Velocity) •İvme (Acceleration)

	-İntegral ve diferensiyel hesaplarda fiziğin konuları içinde kullanılmaktadır. (dy/dx) yolun zamana göre türevi vs.		
22	Türev, İntegral (Birçok konusu, özellikle hareket) Trigonometri (özellikle optik) Analitik geometri (grafik okuma, doğrunun analitiği...) Benzerlik- Alan (Hareket problemleri) Mantık (tüm konular)	•Türev (Derivative) •İntegral (Integral) •Trigonometri (Trigonometry) •Analitik geometri (Analytic geometry) •Geometri (benzerlik, alan) (Geometry) •Mantık (Logic)	•Hareket (Motion) •Optik (Optics)
23	Logaritma: Ses şiddeti birimi desibel logaritmiktir. Optik konusunda da kullanılır. Matris: Elektrik devreleri, optik ve kuantum mekaniğinde kullanılır. Limit: Limit kavramında ortaya çıkan diferansiyel hesap, pek çok fizik probleminin çözümünde kullanılır. Türev: Hareket, ısı problemlerinin çözümünde kullanılır. Doğru boyunca hareket eden bir cismin, t zamanı içinde aldığı yol ile t anındaki hızı ve ivmesi arasındaki ilişki türev ile bulunur. İntegral: İntegral yardımıyla fizikteki doğrusal hareket problemlerini çözebiliriz.	•Logaritma (Logarithm) •Matris (Matrices) •Limit (limit) •Türev (Derivative) •İntegral (Integral)	•Ses şiddeti (Sound intensity) •Optik (Optics) •Elektrik devreleri (Circuits) •Kuantum mekaniği (Mechanics of quantum) •Hareket (Motion) •Hız (Velocity) •İvme (Acceleration) •Isı (Heat)

APPENDIX E: Responses for the second open-ended question

The results of the table below were summarized in Table 5 and Table 6.

Participants	Responses	Topics in Mathematics	Topics in Chemistry
1	Burda da yine türev aklıma geliyor. Türevi anlık hız değişimi olarak tanımlarsak belki kimyasal reaksiyonlarda etkileşim hızı- rate of change le ilgili konularla ilişkilendirilebilir. Ya da polar coordinate gibi konuları organik kimyayla ilişkilendirebiliriz belki. Moleküllerin yapısı gibi vs vs	•Türev (Derivative) •Polar coordinates (Polar coordinates)	•Kimyasal tepkimeler (Chemical reactions) •Organik kimya (Organic chemistry) (e.g.molekül yapısı (structure of molecules))
2	Denklemler, üslü ifadeler, karışım problemleri.	•Denklemler (Equations) •Üslü sayılar (Exponential numbers) •Karışım problemleri (Mixture problems)/Oran-orantı (Ratio-proportion)	
3	Konu Başlıkları: Sayılar, Oran-orantı, Yüzde, Birimler, Fonksiyon ve fonksiyon grafikleri, Logaritma... Örneğin; fonksiyon grafiklerinin ne ifade ettiklerinin daha kolay anlaşılması bakımından "Kimya" dersinde deneyler sonucu elde edilen veriler koordinat sistemi üzerine yerleştirilerek grafikler çizilebilir. Ve ilgili grafiğin bir fonksiyon gösterip göstermediği ve fonksiyon gösteriyorsa bunun hangi fonksiyon olabileceği öğrencilerle tartışılabilir.	•Sayılar (Numbers) •Oran-orantı (Ratio-proportion) •Birimler (Units) •Fonksiyonlar (Functions) •Fonksiyon grafikleri (Graphs of functions) •Logaritma (Logarithm)	•Deney sonuçları (Results of experiments)
4	9. sınıf Sayılar (sözel problemlerde çözelti problemleri bu bağlamda düşünülebilir.) Logaritma (kimyada ograitmik ölçekler kullanılmakta. Birçok kimyasal bağıntı da logaritma içermete. Örneğin, hidrojen atomu sayısı ve pH ölçüsü gibi)	•Sayılar (Numbers) •Karışım problemleri (Mixture problems) •Logaritma (Logarithm)	•Çözelti problemleri/Karışım problemleri (Mixture problems) •pH ölçümü (Measuring pH)

5	Kimya konusunda bilgim yok.		
6	Fonksiyonlar ve grafikleri: Kimyasal denklemlerin dengelenmesi, asit-baz konusu, oksitlenme gibi konularla ilişkilendirilerek. Sayılar (üslü sayılar, oran-orantı): karışım, çözelti, bileşikler, kimyasal reaksiyonlar konuları ile ilişkilendirilerek Geometrik şekiller, Açı ve Uzaklık ölçümü: Bağlar arasındaki açı ve moleküldeki atomlar arasındaki uzaklık Logaritma: pH değeri hesaplamaları 2. dereceden denklemler, eşitsizlikler	•Fonksiyonlar (Functions) •Fonksiyon grafikleri (Graphs of functions) •Üslü sayılar (Exponential numbers) •Oran-orantı (Ratio-proportion)/ Karışım problemleri (Mixture problems) •Açılar (Angles) •Uzaklık ölçümü (Distance measurements) •Logaritma (Logarithm) •2. Dereceden denklemler (Second degree equations) •Eşitsizlikler (Inequalities)	•Kimyasal denklemlerin dengelenmesi (Balancing chemical reactions) •Asit-baz (Asid-Base) •Oksitlenme (Oxidation) •Karışım problemleri (Mixture problems) (e.g. çözeltiler (solutions)) •Bileşikler (Compounds) •Kimyasal reaksiyonlar (Chemical reactions) •Bağlar arasındaki açı (Angles between chemical bonds) •Moleküldeki atomlar arası uzaklık (Distance between the atoms in molecules) •pH ölçümü (Measuring pH)
7	Matematikteki problemler konusu kimyayla entegre edilebilir. Örneğin karışım problemleri Deneysel çalışmalara istatistik iyi bir şekilde entegre edilebilir. Sayıların kullanımı kimyayla entegre edilebilir (Avagadro sayısı)	•Karışım problemleri (Mixture problems) •İstatistik (Statistics) •Sayılar (çok büyük çok küçük sayılar)(Scientific notation)	•Karışım problemleri (Mixture problems) •Deneyler (Experiments) •Avagadro sayısı (Avagadro number)
8	Tüm sayısal işlem becerileri (dört işlem, kesirli sayılar, oran-orantı, ondalıklı sayılar, köklü ve üslü sayılar,...). Fizik dersinde olduğu gibi yukarıda saydığım tüm işlem becerileri kimya dersinde de kullanılmaktadır. Ayrıca karışım problemleri, çok büyük çok küçük sayılar, gibi konular kimya derslerinde kullanılmaktadır.	•Sayılar (Numbers) •Oran-orantı (Ratio-proportion) •Karışım problemleri (Mixture problems) •Üslü, köklü sayılar (Exponential and root numbers) •Çok küçük ve çok büyük	•Karışım problemleri (Mixture problems)

		sayılar(Scientific notation)	
9	Kimyasal tepkimelerde ve ayrıca Asit-Baz konusunda pH ve pOH'ı bulurken logaritma kullanıldığı için logaritma konusu kimya entegrasyonuna uygun bir konudur.	•Logaritma (Logarithm)	•Kimyasal tepkimeler (Chemical reactions) •Asit-baz (Asid-Base) •pH ölçümü (Measuring pH)
10	Denklemler, hacim hesapları ve karışım problemleri örnek olarak verilebilir.	•Denklemler (Equations) •Hacim (Volume) •Karışım problemleri (Mixture problems) / Oran-orantı (Ratio-proportion))	
11	1) Logaritma konusu, radyoaktivite konusuna entegre edilebilir.	•Logaritma (Logarithm)	•Radyoaktivite (Radioactivity)
12	Logaritma	•Logaritma (Logarithm)	
13	Oran-orantı konusunda bileşikleri oluşturan elementlerin veya atomların oranları ile ilgili örnekler verilebilir.	•Oran-orantı (Ratio-proportion)	•Bileşikler (Compounds) •Karışımlar (Mixtures)
14	Ondalık sayılar, reel sayılar, üslü sayılar, 1. ve 2. dereceden denklemler	•Sayılar (Numbers) •Üslü sayılar (Exponential numbers) •1. Dereceden denklemler (First degree equations) •2.dereceden denklemler (Second degree equations)	
15	İşlemler konusu	•İşlemler (Operations)	
16	Lise 1 de çok büyük ve çok küçük sayılarla şlem yapabilme. 11. sınıf (IB) logaritma uygulamaları	•Çok büyük ve çok küçük sayılar (Scientific notation) •Logaritma (Logarithm)	
17	Logaritmik ve üstel fonksiyonlar kimyada half life, radioactive decay konuları ile bağlantılı	•Logaritma (Logarithm) / Üstel fonksiyon (Exponential function)	•Radyoaktivite (Radioactivity)
18	Birinci dereceden çok bilinmeyenli denklemler hess yasasını kullanarak	•Birinci dereceden denklemler (First	•Hess yasası (Hess principle)

	kimyasal tepkimelerde ısı hesaplarına uygulanabilir.	degree equations)	
19	Logaritma ve üstel fonksiyonlar örneğin radyoaktif çürüme, yarı ömür gibi kimya problemlerinde bu konuların bilinmesi gerekmektedir.	•Logaritma (Logarithm) / Üstel fonksiyon (Exponential function)	•Radyoaktivite (Radioactivity) (e.g yarı ömür (half life))
20	Oran-orantı: Karışım-bileşim problemlerinde Logaritma: Atomik yarılanma problemlerinde, hesaplamalarda Türev-integral: Fiziko kimya problemlerinde	•Oran-orantı (Ratio-proportion) / Karışım problemleri (Mixture problems) •Logaritma (Logarithm) •Türev (Derivative) •İntegral (Integral)	•Karışım problemleri (Mixture problems) •Radyoaktivite (Radioactivity) •fiziko kimya problemleri (Physics-chemistry)
21	Matematiksel işlemler, özellikle üslü sayılar, ondalık sayılarla ilgili denklem çözümleri. Oran-orantı konusu oldukça fazla kullanılmakta. Logaritma ve katı cisimlerin hacimleri (gazlar ve sıvılarla ilgili olarak)	•Sayılar (Numbers) •Üslü sayılar (Exponential numbers) •Oran-orantı (Ratio-proportion) •Logaritma (Logarithm) • Katı cisimlerin hacimleri (Volume)	•Gazların ve sıvıların hacimleri (Volumes of gase and liquids)
22	Oran-Orantı (Tepkime hseapları) Analitik geometri (Grafik okuma, yorumlama) Denklem çözümleri(Her konu) Geometri (katı cisimler, organik) Mantık (tüm konular) Logaritma (Radyoaktivite)	•Oran-orantı (Ratio-proportion) •Analitik geometri (Analytic geometry) •Grafik (Graphs) •1. ve 2. Dereceden denklemler (First and second degree equations) •Geometri (Geometry) •Mantık (Logic) •Logaritma (Logarithm)	•Kimyasal tepkime (Chemical reactions) •Organik kimya (Organic chemistry)
23	Logaritma: PH hesaplamalarında Elektrokimya'da kullanılır. Oran Orantı: ve üslü sayılar kimya problemlerinin çözümünde kullanılır. Türev Isı konusunda kullanılabilir.	•Logaritma (Logarithm) •Oran-orantı (Ratio-proportion) •Üslü sayılar (Exponential numbers) •Türev (Derivative)	•pH ölçümü (Measuring pH) •Karışım problemleri (Mixture problems) •Tepkime ısısı (Heat of reactions)

APPENDIX F: Responses for the third open-ended question

The results of the table below were summarized inTable 5 and Table 6.

Participants	Responses	Topics in Mathematics	Topics in Biology
1	Aklıma ilk gelen üslü sayılar ve de hücre bölünmesi geldi. Mitoz bölünme. Yine Türev ve rate of reaction olabilir.	•Üslü sayılar (Exponential numbers) •Türev (Derivative)	•Mitoz bölünme (Mitosis)
2	Denklemler, üslü ifadeler. Bunlar aklıma gelenler, temel ilgi alanım lise matematiği olmadığı için çok ilgilenmiyorum ve size de örnek veremiyorum.	•Denklemler (Equations) •Üslü sayılar (Exponential numbers)	
3	Konu Başlıkları: Kümeler, Sayılar, Permütasyon, kombinasyon ve olasılık, Oran-orantı, Yüzde, Birimler, Fonksiyon ve fonksiyon grafikleri, Logaritma... Örneğin kümeler konusuna Biyolojiden; örneğin "CANLILARIN ORTAK ÖZELLİKLERİ nelerdir?" şeklinde bir soru örnek olarak verilebilir.	•Kümeler (Sets) •Sayılar (Numbers) •Permütasyon (Permutation) •Kombinasyon (Combination) •Olasılık (Probability) •Oran-orantı (Ratio-proportion) •Yüzde hesapları (Percentage) •Birimler (Units) •Fonksiyonlar (Functions) •Fonksiyon grafikleri (Graphs of functions) •Logaritma (Logarithm)	•Canlıların özellikleri (Properties of creatures)
4	Olasılık-İstatistik (genetik araştırmalarda olasılık ve istatistik kullanılmakta, örneğin hastalıkların nesiller arası geçiş ve görülme olasılıkları. Bu bağlamda ilişki kurulabilir.)	•Olasılık (Probability) •İstatistik (Statistics)	•Genetik (Genetics) (e.g pedigri ağacı (pedigree tree))
5	Olasılık ve istatistik genetikte kullanılabilir.	•Olasılık (Probability) •İstatistik (Statistics)	•Genetik (Genetics)
6	Olasılık ve istatistik: Genetik yapı ve kalıtım konuları ile ilişkilendirilerek	•Olasılık (Probability)	•Genetik (Genetics)

	Türev, Fonksiyonlar, 2. dereceden denklemler: Popülasyon artışı-azalışı, popülasyonu sabitleme, vücuda alınan ilacın seviyesinin zamanla değişimi, karbon miktar ölçümü ile madde yaşının tespiti konuları ile ilişkilendirerek Türev, limit: Çevre kirliliği konusu ile ilişkilendirilerek	•İstatistik (Statistics) •Türev (Derivative) •Fonksiyonlar (Functions) •2. Derece denklemler(Second degree equations)	•Populasyon artış ve azalışı (Increase and decrease in population) •İlaç dozu (Dose of medicine) •Karbon yaşı (Carbon dating) •Çevre kirliliği (Pollution)
7	Olasılık konusuyla genetik konuları entegre edilebilir Grafik yorumlamalar bir çok konuyla entegre edilebilir Deneysel çalışmalara istatistik iyi bir şekilde entegre edilebilir.	•Olasılık (Probability) •Grafik (Graphs) •İstatistik (Statistics)	•Genetik (Genetics) •Deneyler (Experiments)
8	Biyolojide bilimsel gösterim, üslü sayılar, genetikte kullanılan olasılık ve yüzde hesaplama ve dört işlem becerisi kullanılmaktadır.	•Bilimsel gösterim (Scientific notation) •Üslü sayılar (Exponential numbers) •Olasılık (Probability) •Yüzde hesaplama (Percentage) •İşlem (Operations)	•Genetik (Genetics)
9	İstatistik konusun biyoloji entegrasyonuna uygun bir konu olduğunu düşünüyorum. Pek çok deneyin yapıldığı biyoloji alanında çeşitli istatiksel metotlar kullanılmaktadır. Bu metotlar yardımıyla verilerin toplanması, analiz sonuçlarının değerlendirilmesi, çeşitli dağılımların kullanılması gerektiğinden istatistik konusu ile yapılacak entegrasyon faydalı olacaktır. Ayrıca genetik ve olasılık konulu bir bütünleşmenin de uygun olduğunu düşünüyorum.	•İstatistik (Statistics) •Olasılık (Probability)	•Deneyler (Experiments) •Genetik (Genetics)
10	Kümeler, olasılık ve denklemler örnek olarak verilebilir.	•Kümeler (Sets) •Olasılık (Probability) •Denklemler (Equations)	
11	1) Olasılık konusu, Genetik konusuna entegre edilebilir. 2) Üstel ve logaritmik fonksiyonlar, popülasyon artışı konusuna entegre edilebilir.	•Olasılık (Probability) •Üstel fonksiyon (Exponential function) •Logaritma (Logarithm)	•Genetik (Genetics) •Popülasyon (Population)

12	Logaritme	•Logaritma (Logarithm)	
13	Katılımda olasılık teorisinden yararlanılarak öngörüler yapılabileceği örnek olarak verilebilir. Popülasyon artışları ve belli zaman aralıklarında bir popülasyona ait canlı sayısını bulmada matematiksel modellemeden yararlanılabilir. Üstel fonksiyon konusu bu tarz örnekler için kullanılmaktadır.	•Olasılık (Probability) •Üstel fonksiyon (Exponential function)	•Genetik (Genetics) •Popülasyon (Population)
14	ondalık sayılar, reel sayılar, üslü sayılar	•Sayılar (Numbers) •Üslü sayılar (Exponential numbers)	
15	fonksiyonlarda grafik çizimleri dna grafikleri ile bağlaştırılarak.	•Fonksiyonlarda grafik (Graphs)	•Genetik (Genetics) (e.g. DNA grafikleri (DNA graphs))
16	IB sınıflarında istatistik anlatılıyor. Biyolojide bu konudan faydalanıyor.	•İstatistik (Statistics)	
17	Bakterilein çoğalması, nüfus problmleri, üstel ve logaritmik fonksiyonlar p(t)=50.2^t Kaç saat sonra şu kadar bakteri olur etc.	•Üstel fonk (Exponential func) •Logaritmik fonk (Logarithmic functions)	•Popülasyon (Population) (e.g Bakteri artışı (Bacterial population growth))
18	Türev ve integralin yara kapanma hızını belirlemede kullanılabildiğini söylemek ve bir örnekle bunu göstermek biyoloji matematik işbirliğine katkıda bulunabilir.	•Türev (Derivative) •İntegral (Integral)	•İyileşme süresi (Recovery time)
19	Populasyon artışı gibi problemlerde üstel fonksiyon ve logaritma bilinmelidir. Ayrıca istatistikte de biyoloji ile ilgili konularda kullanılır.	•Üstel fonksiyon (Exponential function) •Logaritma (Logarithm) •İstatistik (Statistics)	•Popülasyon (Population)
20	Üstel-logaritma fonksiyonları: nüfus artışları problemlerinde Kombinasyon-olasılık: aile çoğalmaları, hücre bölünmeleri problemlerinde	•Üstel fonksiyon (Exponential function) •Logaritma (Logarithm) •Kombinasyon (Combination) •Olasılık (Probability)	•Popülasyon (Population) •Hücre bölünmesi (Segmentation)
21	İstatiksel analizler. Grafik çizimleri (hücrelern artış, azalış hızlarını gösterirken grafik çizimleri yapılır ve yorumlanır)	•İstatistik (Statistics) •Grafik (Graphs)	•Hücre bölünmesi (Segmentation) •Popülasyon(Popul

	olasılık (genetik konusu, mendel çaprazlaması) Logaritma (hücre artış, azalış ve ya bakterilerin üreme hızı)	•Olasılık (Probability) •Logaritma (Logarithm)	ation) •Genetik (Genetics) (e.g Mendel çaprazlanması (Mendel-cross breeding))
22	Olasılık (Genetik) İstatistik (Genetik) Türev (Daha ileri düzey için) Mantık (Tüm konular) Logaritma (üreme)	•Olasılık (Probability) •İstatistik (Statistics) •Türev (Derivative) •Mantık (Logic) •Logaritma (Logarithm)	•Genetik (Genetics) •Popülasyon (Population) (e.g.üreme (reproductivity))
23	Türev, diziler (Geometrik diziler), Logaritma. Biyolojide bakterilerin büyüme hızı, maksimum büyüme hızı türev ile bulunur. Nüfus artışı yine türevle hesaplanabilir. Bakteri artış miktarı yine geometrik dizi ile ilişkilendirilebilinir. Yıllık nüfus artış hızı nüfusun yıllar içinde ne kadar artacağının buldurulması için üslü ve logaritmik denklemler yardımıyla bir matematiksel modelleme yapılabilir.	•Türev (Derivative) •Diziler (Sequences) •Logaritma (Logarithm)	•Büyüme hızı (Rate of growth) •Nüfus artışı (Increase in population) •Bakteri artışı (Bacterial population growth)

APPENDIX G: Responses for the fourth and fifth open-ended questions

The results of the table below were summarized in Figure 4 and Figure 6.

Participants	4. Sizce matematik için fen bilimleri entegrasyonunun öğrencinin öğrenim sürecine katkı sağlayacak olan avantajları neler olabilir? Lütfen fikirlerinizi örneklerle açıklayınız.	5. Türkiye koşulları çerçevesinde düşünüldüğünde, matematik için fen bilimleri entegrasyonunun öğrencinin öğrenim sürecinde etkili olabilecek dezavantajları ve sınırlılıkları nelerdir? Lütfen fikirlerinizi örneklerle açıklayınız.
1	1) Kısmen de olsa "bunlar bizim ne işimize yarayacak" sorusuna cevap verebilir. 2) Matematiğin soyut dünyasından çıkıp, elle tutulur sonuçlara ulaşmasını sağlar.	Herhangi bir dezavantaj getireceğini düşünmüyorum. Sadece Fen grubu derslerinin işlenmesinde karşılaşılan, yani zaten var olan dezavantajların yansımaları olabilir.
2	Öğrencinin öğrenme isteği ve motivasyonu artar. Daha kolay ve kalıcı öğrenir	Öğretmen yeterince bilgili olamazsa, öğrenciye yetersiz kalabilir. Teknolojinin kullanımı entegrasyonu daha kolay sağlayacağından, teknolojinin sağlanma sıkıntısı yaşanabilir.
3	* Fen bilimlerine ilgi duyan öğrenciler için, matematik ve fen bilimleri entegrasyonu, matematiksel kavramları ve uygulamaları öğrenmelerinin ne kadar yararlı olacağı konusunda içsel bir motivasyon sağlayabilir. * Öğrenilen bir kavramın farklı bağlamlar içinde kullanıldığını görmek, kavramın daha derinlemesine anlaşılmasına ve içselleştirmesine fayda sağlayabilir. *Matematiğin tüm bilimler için gerekli bir dil olduğunu görmelerini sağlayabilir. Bu dili kullanmanın, gelecek akademik yaşantıları için ne denli önemli olduğu konusunda farkındalık yaratabilir.	* Öğretmenlerin esnek olmayan ve oldukça yoğun bir müfredatı öğrencilere aktarma çabası sırasında,gerek zaman gerek emek isteyen farklı uygulamalara yer verme konusundaki isteksizlikleri, söz konusu entegrasyon için bir sınırlama getirebilir. *Matematik ve fen bilimleri entegrasyonunun sağlanabilmesi adına, matematik öğretmenlerinin, fen bilimlerinden yardım alacakları konularda doğru bağlantıları yapabilmeleri ancak bu alanlarda derin bir bilgi birikimine sahip olmalarıyla mümkündür. Aksi takdirde eksik ya da yanlış bağlantılar, öğrencilerde kavram kargaşasına yol açabilir * Öğrencilerin fen bilimlerindeki eksik bilgileri, entegre edilen konuyu anlamayı desteklemekten çok güçleştirebilir. Bu noktada öğretmenin, sınıfın yapısına göre farklı yollar tercih etmesi gerekir.
4	1) Dersler arasında ilişkilendirme yapar 2) Neden öğreniyorum sorusuna bazı cevaplar bulur 3) Neden öğrendiğini anlarsa öğrenmeye daha istekli olur 4) ilişkilendirme yaparak daha kolay öğrenir	1) Ülkenin her yerinde aynı koşullar olmadığı için bazı zorluklar yaşanabilir, ilişkilendirmeler istenilen şekilde yapılamayabilir 2) Öğretmenler bu şekilde eğitilmediği için ilişkilendirmeler istenilen şekilde yapılamayabilir
5	Matematik konularının soyut kalmasından kurtulmasını sağlayacağını	Dezavantaj sağlayacağını düşünmüyorum.

	düşünüyorum	
6	Öğrenci zor bir konuyla karşılaştığında "Hocam bu ne işimize yarayacak? Nerede kullanacağız?" diye sorular sorarlar. Öğrencinin konuya hâkim olabilmesi, EZBERLEMEMESİ için o konunun güncel yaşantıya uygulanmasını da görmesi konuyu etkili bir şekilde kavramasını sağlayacaktır.	Fen derslerinden önce konuyu matematik dersinde görüp, uygulamasını fen derslerinde yapabiliyorsa bilgi pekişir. Ancak çoğu konu önce fen derslerinde ezbere kullanılıyor, daha sonra matematikte detaylandırılıyor (trigonometri, türev gibi)
7	-Öğrencilerin genellikle sorduğu bu konu ne işimize yarayacak sorusuna cevap verir. -Fen bilimlerindeki konuların daha çok özümlememizi sağlar. -Derse olan ilgisi artar.	-Konu sayısı, ders sayısı çok fazla -Her konunun bağlantısı kurulabilir ancak süre ve koşullar yetersiz -Avrupa'daki eğitim öğretim bizden en temel farkı uygulamaya daha fazla ağırlık verilmesi -Bizde teori ve "find x" tipi sorular ağırlıkta
8	1. Öğrenci deyimiyle; fen bilimleri gündelik hayatla daha iç içe olduğu için matematiğin de gündelik hayatta kullanılır bir bilim olduğunun anlaşılmasında yardımcı olur. 2. Fiziksel, kimyasal ve biyolojik süreçlerin incelenmesinde matematiğin vazgeçilmez bir araç olduğunun fark edilmesiyle öğrencilerin edinecekleri mesleklerde gösterecekleri başarının matematik bilgisiyle ilişki içinde olduğunu fark etmelerine katkıda bulunur. 3. Öğrencilerin vazgeçilmezi olan teknolojik araçların geliştirilmesinde matematiğin rolünün büyük olduğunu fark etmeleri sağlanırsa matematik düşmanlığının giderilmesinde ufak da olsa bir adım atılabilir.	1. Soyut düşünmeden uzaklaşılabilir 2. Fen bilimlerinde çok kullanılan deney yönteminin matematikte de işlerliği olduğu yanılgısına düşülüp tutarlı ispat yapma yeteneğinin gelişmesi zora sokulabilir. 3. Elle tutulur bir işe yararlık bulma isteği daha da artabilir ve "4 işlemden başkası gereksizmiş benim için" noktasına dönülebilir
9	Fen bilimlerindeki konuların görsel materyallerle desteklenmesi daha rahat olduğundan konuyu soyut olmaktan çıkarıp daha somut bir hale getirir. Öğrencinin gerçek yaşamla konu arasında bağ kurmasını kolaylaştırır. Matematiğin işe yaramadığı yanılsamasını ortadan kaldırmaya yardımcı olur.	Müfredat bu tür konular dikkate alınarak hazırlanmadığından sıkıntı yaşanabilir. Yeterli kaynak bulmak zor olabilir. Okullarda verilen eğitin genelde üniversiteye giriş sınavına yönelik olduğundan ve öğrencilerin beklentisi ve talepleri bu yönde olduğundan dolayı bu tarz bir yaklaşım öğrencilere çok hitap etmeyebilir. Öğretmenlerinde fen bilimleri alanı hakkında bilgi sahibi olmaları gerekir.
10	-Matematiğin soyut yapısının yaşamla bağı olduğunu gösterir. -Fen bilimlerinin daha iyi anlaşılmasını grafikle anlayıp, hesaplamaların kolaylaşmasını sağlar.	Matematiğin, fen bilimleri eğitimine dezavantaj sağladığını düşünmüyorum.

	-Fen bilimlerinin ezber kısmını kaldırıp anlamların tam anlaşılmasını sağlar.	
11	-Öğrenilen matematik konularının diğer alanlarda kullanımı bilginin kalıcı olmasında yarar sağlar. -Kullanım alanlarını öğrendikçe bilgiye daha çok ihtiyacı olduğunu anlar. -Öğrendiği matematik konularının somutlaşmasını sağlar.	-Matematik eksik olursa diğer derslere uygulaması tekrar sorun yaratabilir. -önemli bir dezavantaj oluşturacağını düşünmüyorum.
12	- öğrendiği konuların yaşamın hangi alanlarında kullanılabileceğini görmesine yardımcı olur (öğrencilerimizin derslerde genellikle sorguladıkları ve iyi yanıt almadıklarında konuyu sadece not almak için ezberledikleri görülmektedir) -Disiplinler arası çalışmanın önemini kavrar ve bu duruma yatkınlaşır. -Yaşamdaki problemlere daha geniş perspektifle bakmaya alışır. -Bilimsel çalışmalara yatkınlığı artar. -İleride seçeceği mesleğin ne olacağı konusunda kafasında daha belirgin ve doğru yargılar oluşur.	-okullarda yeterli donanım olmadığı takdirde işlevsizleşecek ve daha da kötüsü, öğrencilere daha ağır yük getirmekten başka bir şeye yaramayacaktır. -Öğretmenlerin yetiştirilmesinin tamamen farklılaşması gerekecektir ki ülkemiz koşullarında çok kolay görülmemektir. Donanımsız öğretmenlerle mevcut durum iyileşeceğine kötüye gider. -Ülkemiz koşullarında, bir öğrencinin bilim insanı olmaya karar vermesini zorlaştırabilir.
13	1 Bilimsel düşünceyi geliştirir. 2 Disiplinler arasındaki ilişkiyi arttırır. 3 Analiz, sentez ve yorum yeteneğini geliştirir.	Fen bilimleri entegrasyonunun öğrencinin öğrenim sürecine katkısının olabilmesi için matematik, fizik, kimya ve biyoloji derslerini okutan öğretmenlerin kendi aralarında iletişim içerisinde olmaları gerekir. Fikir birliği içinde olarak aynı düşünce ile hareket etmeleri gerekir. Birbirlerinden yardım almaları ve entegrasyonun gerçekleşmesini birlikte sağlamalılar. Aksi takdirde dersler arasında iletişim kopukluğu olursa entegrasyon sağlıklı bir şekilde gerçekleşmez.
14	4aGünlük yaşam örneklerinin onların daha çok ilgisini çekeceğini düşünüyorum. Sayılar-semboller yerine bu da burada kullanılıyormuş diyebilecek. Terside doğru olabilir. Aslında fen dersinde de matematiğin faydasını görebilecek. Öğrenilenin kalıcılığı artacak. Disiplinler arası ilişkiler öğrencilerin ilişki kurmalarını sağlayacağından kavramsal öğrenmenin de artacağını düşünüyorum..	İki dersin entegrasyonun dezavantajı şöyle olabilir. Öğrenci fen bilimlerini sevmiyorsa matematikten de soğuyabilir. Bunun terside mümkün. Öğrenci fenle ilgili konuya aşina değilse oradaki matematiği yapmak istemeyebilir. Öğrencilerin adaptasyonu zorlaşabilir. Odaklanmaları gereken değişken sayısı arttığında ilgi ve motivasyonları azalabilir.
15	Matematiğin farklı bilim dallarında uygulandığını gözlemlemek öğrencilere matematiğin önemini vurgulayabilir. Ayrıca öğrencilerin bizlere sıklıkla sorduğu "Şimdi bu konu ne işimize yarayacak? Nerede kullanacağız bu	En başta, hali hazırda yoğun olan matematik müfredatına yeni eklemeler yapılması konuların yetişme telaşını artırabilir. Ayrıca fen alanı derslerinden hoşlanmayan öğrencilerin matematiğe

	bilgileri?" gibi sorularına çok güzel cevap olmuş olur.	yaklaşımını da olumsuz yönde etkileyebilir.
16	Konular arasında yapılacak ilişkilendirmeler sayesinde bir derste öğrenilenlerin diğer derste de kullanılmasıyla öğrenme hızlandırılabilir.	Öğrencinin konuya karşı önyargı oluşturarak öğrenmeye yönelik algılarını kapatmasına neden olabilir. Örneğin, vektörler konusunu matematik dersinde anlamayan bir öğrenci fizik dersinde aynı konuyla karşılaştığında bu konu zor diyerek dinlemeyi ve öğrenmeyi reddedebilir.
17	1. Matematik için fen bilimleri entegrasyonu sayesinde öğrenciler disiplinler arası ilişkinin öneminin farkında olurlar. 2. Örneğin;biyoloji, fizik ve kimya disiplinlerinde gerçek hayat problemlerini göstermek daha kolaydır. Bu nedenle öğrencilere, matematik dersinde konulara uygun biyoloji, fizik ve kimya konularından örnekler verilerek öğrencilere matematik konularının öğrenilmesinin gerekliliği ve önemi benimsetilebilir. 3. Öğrencilerin matematik dersinde öğrendikleri formülleri fen bilimlerinde kullanmalarını sağlayarak, öğrendiklerinin kalıcılığı sağlanabilir (Not: Öğrencilerin öğrenirken formülleri ezberleme şeklinde değil de anlayarak öğrenmeleri sağlanabilir). 4. Matematik için fen bilimler entegrasyonunun öğrencilere avantaj sağlamasının yanında, bunu uygulayabilen öğretmenler için de avantaj sağlayabileceği kaçınılmazdır. Örneğin öğrencilere, türev konusu öğretilirken fizik dersindeki hız konusu ile bağlantı kurularak, türev hakkında öğrencide merak uyandırılabilir. Bir başka örnek olarak biyolojide bakterilerin çoğalma hızı, nüfusun artması gibi örnekler verilebilir(Not: Her ne kadar bu örnek bir diferansiyel denklemle ifade edilse de burada sadece birinci mertebeden türevin bilinmesinin yeteceği unutulmamalıdır. Yani öğrencilerin basit formüllerle sonuca ulaşmalarının yerine, öğrencide matematiksel düşünmenin ve sorgulamanın geliştirilmesi için yukarıdaki gibi örnekler verilebilir. Ancak bu biçimdeki örneklerin konu başlangıcında verilmesi, konunun	Matematik için fen bilimleri entegrasyonu çok önemli olacaktır. Ancak Türkiye'deki tüm ortaöğretim kurumları dikkate alındığında, başlangıçta öğretmenlerin fen bilimlerini matematiğe entegre edebilmelerinde sıkıntılar yaşanabilir. Örneğin; Ortaöğretim kısmı için matematik öğretmeni yetiştirme programları incelendiğinde programlarda "Kimya ve Fizik" derslerinin yer aldığı, ancak "Biyoloji" dersinin yer almadığı görülür. Bu da bu matematik öğretmeni yetiştiren programlardan mezun olan öğretmenlerin matematik dersinde biyolojiyi kullanmalarını güçleştirir. Bu ancak öğretmenlerin kendi ilgi ve çabalarıyla gerçekleşebilir. Ortaöğretim kurumlarında genel olarak, farklı disiplinler arasında, bilgi alışverişinin de etkin olarak kullanılamıyor olması bir başka dezavantaj olarak gösterilebilir.

	genelinin daha kolay algılanması için daha etkili olabilir.	
18	Matematik ve fen bilimlerinin birbirleri ile ilgileri olduğunun öğrenciler tarafından anlaşılması sağlanabilir, bunun daha motivasyon yönünden bir avantajı olabilir. Birindeki kavram bilgisi ve becerilerin diğerinde de kullanıldığının farkına varılması, böylece hem kavramların örneklendirilmesi ve daha somut hale getirilmesi, hem de bilginin bir ağ şeklinde zihinsel süreçlerde daha kalıcı olarak yer edinmesi de bilişsel olarak bir avantaj olabilir. Matematik kavramları ile fen alanlarındaki kavramların entegrasyonu aynı zamanda öğrencilerin bu disiplinlerdeki kavram ve süreçleri ifade ederken daha dikkatli ve daha bilimsel bir dil kullanmalarına yardımcı olabilir.	Ben en büyük dezavantajın sınav sistemi ile ilgili olabileceğini düşünüyorum. Entegrasyonun sınav sistemindeki soru çeşitleri ile örtüşmediğini noktada öğretmen ve öğrencilerin böyle bir öğretimi benimsemeyeceklerini ve olumsuz bir tutum geliştireceklerini düşünüyorum. Buna ek olarak öğretmenlerin entegrasyon için yeteri kadar hazır olduklarını sanmıyorum, öğretmen eğiten programlar da hazır değil bence. Bu da entegrasyonun etkisini azaltacaktır.
19	Öncelikle fen bilimleri ve matematikte ortak olabilecek konular tematik bir yaklaşımla programlarda senkronize bir şekilde verilebilir. Bu şekilde öğrenciler aynı/benzer kavramları farklı bağlamlarda gördüklerinde bunları ayrı konular gibi görme eğilimleri minimize edilebilir. Bu şekilde öğretim programlarında aynı konular tekrar tekrar ayrı konularmış gibi ele alınmaz. Bu şekilde zamandan da kazanım olacaktır. Öte yandan daha soyut bir yapısı olan matematiğin konu ve kavramlarının günlük hayatta veya gerçekçi durumlarda ne şekilde kullanıldığı gösterilebilir, bu şekilde öğrencilerin "bunu neden öğreniyoruz? nerede nasıl, kimin işine yarayacak?" gibi sorularına bir ölçüde cevap bulabilir ve öğrenmeye ilgili/motivasyon artırılabilir.	En önemli sorun müfredatların (veya öğretim programlarının) senkronize olmaması. Ortak (veya ilişkilendirilecek) bir konu fizikte 9. sınıfta geçerken, matematikte 12. sınıfta olabilmekte. Sorun oluşturabilecek diğer bir durum günlük hayat bağlantısının nerede ve ne amaçla yapılacağı konusunda farklılıklar öğrencilerin odaklarını farklı noktalara çekebilir. Buda ilgili konunun öğrenimini sekteye uğratabilir, kafa karışıklığı yaratabilir. Diğer taraftan bu tür şeyler kısıtlı olan ders sürelerini iyi kullanamama yönünde de dezavantaj oluşturabilir.
20	Farklı disiplinleri entegre etmenin,eğitimde anlamlı öğrenmenin gerçekleşebilmesi ve farklı bakış açıları yaratmak adına önemli olduğunu düşünüyorum. Özellikle fen matematik entegrasyonu, problem çözmedeki bilimsel yaklaşımların anlaşılması ve anlatılması, öğrencilerin farklı problemlerin çözümü karşısında fen ve matematiksel yeteneklerini kullanabilmeleri, strateji geliştirme, bağımsız olarak çalışabilmeleri açısından	Türkiye koşullarında matematik için fen bilileri entegrasyonunun sınırlılıklarının mevcut olduğu kanısındayım. Şöyle ki; • Öğretmenlerin istekliliğikonu ile ilgili yeterliliği çok önemlidir. • Entegrasyonun her aşamasında öğretmenlerin işbirliği içerisinde olup konuların ilişkilendirilmesi esastır. • Çalışmalar sırasında uygun tekniklerin kullanılması önemlidir. • Matematik için fen entegrasyonunun çok iyi planlanması ve matematik

	önemlidir	kazanımlarının merkeze alınması gerekir.
21	Öğrenci mat-fen entegrasyonu yapılan derste matematiğin gerçek hayat ile ilişkisini görme şansına sahip olabilir ve öğrenci matematiğin nerelerde kullanıldığı, ne işe yaradığı gibi konularda bilgi sahibi olarak matematiğe yönelik olumlu tutum geliştirebilir. Öğrencilerin matematik öğrenmeye yönelik motivasyonunu artırabilir.Mat-fen entegrasyonu öğrencinin matematik ile fen bilimleri arasında daha açık ve anlamlı ilişkiler kurmasını sağlayabilir ve fen alanındaki müfredatın da daha etkili uygulanmasına yardım edebilir.	Böyle bir entegrasyon, eğer müfredatlara bütüncül bir şekilde bakılmadan yapılırsa öğrencilerin bazı konuları yüzeysel bazı konuları gereğinden fazla derinlemesine işlemesine sebep olabilir ve dolaysıyla çok zaman kaybedilmesine yol açabilir. Öğretmenin disiplinler arasındaki entegrasyonu iyi biliyor olmaması öğrencilerin öğrenme sürecini olumsuz etkiler. Matematiksel fikirlerin dersin odağında olması önemlidir, bu tür öğrenme ortamlarında bazen fen konuları ve gerçek hayat durumları odağa alınarak öğrencilerin matematiksel fikirleri kavraması göz ardı edilebilir. Ayrıca her konu için bir entegrasyon mümkün değildir ve zorlama entegrasyonlar öğrencilerin konuları öğrenme ve anlamlandırmalarından daha çok kafa karışıklığına neden olabilir.
22	* Matematiğin diğer alanlarda işe yaradığını görmek * Matematiği fiziksel dünya ile ilgili sorunları çözmede bizzat kullanmak	Entegrasyon süreci iyi yönetilmezse matematik veya fenden bir tanesi feda edilmiş olur. Entegre edilecek kısma yönelik iyi hazırlanmış bir "müfredat" olması gerekir.
23	* Farklı bakış açısı bilişsel gelişime katkı sağlayacaktır. * Öğrenciler kariyer planlarında matematiğin yerini göreceklerdir.. * Fen bilimlerine ilgili öğrencilerin motivasyonu artabilir. * Matematiğin konuları daha somut bir hale gelebilir.	Öğretmek istenilen şey değerlendirmenin bir parçası olmazsa önemsenmez ve yüzeysel kalır. Üniversite giriş sınavında entegre edebilme becerisi ölçülmüyor. Dolayısıyla okullarda da böyle bir ihtiyaç duyulmuyor. Öğretmenler de eğitimli olmadıkları bir konuda eğitim vermek zorlanacaktır. Genelde bir çok öğretmen beni dersimle baş başa bırakın dediğinden entegrasyon çalışmalarına kolay kolay sıcak bakmayacaktır.

APPENDIX H: Cover letter for the second round Likert-scale survey

Mr «TITLE» «NAME» «SURNAME»,

As a graduate student in Bilkent University, Institute of Education Sciences, I collected your opinion about my thesis topic, "Integration of High School Mathematics and Science Curriculum " in first round.

Link of the second (final) round Likert survey is given below. This survey created according to the participants' opinion from the first round. I request you to rank the items. It will take approximately 15-20 minutes to answer.

Please fill the questionnaire within a week for the continuation of the study. Thank you in advance for your participation and support.

Click here for questionnaire: http://t5.ed.or.kr

Sincerely yours,
Tugba Aktan,
Masters in Curriculum and Instuction with Teaching Certificate in Mathematics
Asst. Prof. Dr. Minkee Kim (Supervisor)

APPENDIX I: The second round Likert-scale survey

ADVANTAGES			Agree	No opinion	Disagree
Psychological needs		Translation			
Ps1	Matematik konularını soyut olmaktan çıkarıp daha somut bir hale getirir.	Integration makes mathematics more concrete.			
Ps2	Öğrenciler teknolojik araçların geliştirilmesinde matematiğin rolünü görür.	Students see the role of mathematics in the development of technological tools.			
Ps3	Matematiğin gündelik hayatta kullanılır bir bilim olduğunu görmelerini sağlar.	Integration allows them to see that mathematics as a science is used in everyday life.			
Ps4	Matematiğin tüm bilimler için gerekli bir dil olduğunu görmelerini sağlar.	Integration allows them to see that mathematics is a necessary language for all sciences.			
Ps5	Matematiğe karşı olumlu tutum sergilemelerini sağlar.	It provides them to demonstrate a positive attitude towards mathematics.			
Ps6	Fen bilimlerine ilgi duyan öğrenciler için içsel bir motivasyon sağlar.	It provides an intrinsic motivation for students interested in science.			
Pedagogical needs					
Pd1	Bir konunun birden fazla derste ele alınması öğrenmeyi hızlandırabilir.	It accelerates the learning of a topic that is discussed in more than one course.			
Pd2	Bilginin bir ağ şeklinde zihinsel süreçlerde daha kalıcı ve bilişsel olarak yer edinmesini sağlar.	Information takes place as a network in mental processing more permanently and conceptually.			
Pd3	Öğrencilerin üst seviye düşünce becerilerini (analiz, sentez ve yorum) geliştirir.	It develops students 'higher level cognitive skills (analyze, synthesize, and interpret).			
Sociological needs					
So1	Entegrasyon öğrencilerin bilimsel süreç becerilerinin (strateji geliştirme, bağımsız düşünme, bilimsel dil kullanımı vb.) gelişmesini sağlar.	Integration provides to improve students' science process skills (strategy development, independent thinking, the use of scientific language, etc.).			
So2	Öğrencilerin matematikteki ve fen bilimlerindeki	Students' perceptions of similar concepts in mathematics and			

	benzer kavramları farklı konularmış gibi algılamaları minimize edilir.	science as different topics are minimized.			
So3	Disiplinler arası çalışmanın önemini kavrar ve yaşamdaki problemlere daha geniş bir perspektiften bakar.	Students understand the importance of interdisciplinary studies and they look at the problems in real life wide a wider perspective.			
So4	Öğrenciler kariyer planlarında matematiğin yerini görürler.	Students will see a place of mathematics in their career plans.			
Other needs					
Ot1	Entegrasyonu uygulayabilen öğretmenlere de meraklı öğrenciler sayesinde dersin uygulanış sürecinde avantaj sağlar.	It helps teachers in the implementation process of the course with interested and curious students.			
Ot2	Entegrasyona ait örneklerin konu başlangıcında verilmesiyle konuya ilgi gösterilmesini sağlar.	Samples of integration which are given at the beginning of the subject help to take students' attention easily.			
Ot3	Aynı konular tekrar tekrar ele alınmaz ve zamandan kazananım gerçekleşir.	It provides to save time by not discussing the same topics over and over again.			
DISADVANTAGES					
Constraints related curriculum					
Cc1	Entegrasyon üniversite giriş sınav sistemindeki soru tarzı ile örtüşmediğinden öğretmenler ve öğrenciler entegrasyonu benimsemezler.	Since integration does not overlap with the style of university entrance exam questions, teachers and students don't find the integration useful.			
Cc2	Fen ve matematik müfredatların senkronize olmaması entegrasyon sürecini için önemli bir sorundur.	Science and mathematics curricula which don't synchronize are an important problem for the integration process.			
Cc3	Entegrasyon, müfredatlara bütüncül bir şekilde bakılmadan yapılırsa çok zaman kaybedilmesine yol açar.	Integration which is planned without a holistic approach lead to the loss of a lot of time.			
Cc4	Hali hazırda yoğun olan matematik müfredatımıza yeni eklemeler yapılması	New addition to our curriculum of math which is already intense increases the rush to finish the			

	konuların yetişme telaşını artırır.	topics.			
Constraints related teachers					
Ct1	Matematik öğretmeni yetiştiren programlarda fen bilimlerinin yeteri kadar yer almaması entegrasyonu gerçekleştirmeyi güçleştirir.	Mathematics teacher training programs which does not give enough place to science makes integration difficult.			
Ct2	Fen Bilimleri alanında derin bilgisi olmayan öğretmenlerin kurduğu bağlantılar öğrencilerde kavram kargaşasına yol açabilir.	Links which are established by teachers who don't have deep knowledge on science can lead lots of confusion.			
Ct3	Öğretmenler arasındaki iletişim kopukluğu entegrasyonun sağlıklı bir şekilde gerçekleşmesini engeller.	Lack of communication between teachers prevents the occurring of integration in a healthy way.			
Ct4	Öğretmenlerin zaman ve emek isteyen uygulamalardaki isteksizlikleri entegrasyon için sınırlama yaratır.	Reluctance of teacher because of the activities required time and effort creates limitation for the integration.			
Ct5	Ders planırken matematik konuları yerine fen konuları ve gerçek hayat durumları odağa alınarak öğrencilerin matematiksel fikirleri kavraması göz ardı edilebilir.	Mathematical ideas are ignored by putting science and real life situations to the focus of students instead of mathematics.			
Constraints related students					
Cs1	Fen bilimlerinden hoşlanmayan öğrencilerin matematiğe, matematikten hoşlanmayan öğrencilerin fen bilimlerine karşı olumsuz tutum sergilemesine neden olur.	Integration causes students who do not like science to exhibit negative attitudes towards mathematics and who do not like mathematics to exhibit negative attitudes towards to science.			
Cs2	Öğrencilerin odaklarını farklı noktalara çekerek ilgili konunun öğrenimini zorlaştırır.	Integration attracts students' focuses to other points so it makes learning difficult.			
Cs3	Öğrencileri soyut düşünmeden uzaklaştırır.	Integration prevents students' abstract thinking.			
Cs4	Öğrencilerin fen bilimlerinde kullanılan deney yönteminin	The experimental method used in science causes students to think the method can be used in			

	matematikte de kullanılabileceğini düşünüp tutarlı ispat yapma yeteneğinin gelişmesi engeller.	mathematics and so integration prevents to develop the ability to prove.			
Constraints related facilities					
Cf1	Her konu için entegrasyon mümkün değildir.	Integration is not possible for each topic.			
Cf2	Okullarda (teknoloji kullanımı gibi) yeterli donanımlar olmadığı takdirde entegrasyon işlevsizleşir.	If there isn't enough equipment (such as the use of technology) in schools, it makes integration nonfunctional.			
Cf3	Ülkenin her yerinde aynı koşullar olmadığı için entegrasyon sürecinde zorluklar çıkar.	Challenges in the integration process occur because of the different conditions in all over the country.			
Cf4	Müfredat entegrasyona uygun düzenlenmediğinden kaynak sıkıntısı vardır.	Curriculum is not regulated for the integration therefore there is limited resource.			

APPENDIX J: Screen shot of the online second round Likert scale survey

Matematik Eğitiminde Delphi Anket Çalışması 2. Etap Likert Ölçeği

Birinci etap açık uçlu sorularda belirtilen görüşler doğrultusunda hazırlanan ikinci etap likert tipi anketi oylamanız yaklaşık 15-20 dakikanızı alacaktır.
Amaç ilk etapta toplanan fikirlerin oylanarak ortak bir sonuç elde edilmesidir.
* Required

İsim,Soyisim *

Kısım A: Matematik için Fen Bilimleri Entegrasyonu

Bu bölümdeki sorular lise matematik müfredatında matematik ve fen bilimlerinin entegrasyonu ile ilgilidir.

Matematik için fen bilimleri entegrasyonunun öğrencinin öğrenim sürecine dönük avantajları *

	Fikrim Yok	Katılmıyorum	Katılıyorum
A1. Matemetik konularını soyut olmaktan çıkarıp daha somut bir hale getirir.	○	○	○
A2. Öğrenciler teknolojik araçların geliştirilmesinde matematiğin rolünü görür.	○	○	○
A3. Matematiğin gündelik hayatta kullanılır bir bilim olduğunu görmelerini sağlar.	○	○	○
A4. Matematiğin tüm bilimler için gerekli bir dil olduğunu görmelerini sağlar.	○	○	○
A5. Matematiğe karşı olumlu tutum sergilemelerini sağlar.	○	○	○
A6. Fen bilimlerine ilgi duyan öğrenciler için içsel bir motivasyon sağlar.	○	○	○
A7. Bir konunun birden fazla derste ele alınması öğrenmeyi hızlandırabilir.	○	○	○
A8. Bilginin bir ağ şeklinde zihinsel süreçlerde daha kalıcı ve bilişsel olarak yer edinmesini sağlar.	○	○	○
A9. Öğrencilerin analiz, sentez ve yorum yeteneğini geliştirir.	○	○	○
A10. Entegrasyon öğrencilerin bilimsel süreç becerilerinin (strateji geliştirme, bağımsız düşünme, bilimsel dil kullanımı vb.) gelişmesini sağlar.	○	○	○
A11. Öğrencilerin matematikteki ve fen			

APPENDIX K: Responses for the second round Likert scale survey

Participant	Ps1	Ps2	Ps3	Ps4	Ps5	Ps6	Pd1	Pd2	Pd3	So1	So2	So3	So4	Ot1	Ot2	Ot3
1	A	A	A	A	A	A	A	A	D	A	D	A	D	A	D	A
2	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
3	A	D	A	D	A	A	A	A	A	A	A	A	A	A	A	A
4	A	A	A	A	A	A	A	A	A	A	N	A	A	A	A	N
5	A	A	A	A	A	D	A	D	D	N	A	A	D	D	A	A
6	A	A	A	A	A	A	A	A	A	A	N	A	N	A	A	A
7	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
8	A	N	A	A	A	A	A	A	N	N	A	A	A	N	N	N
9	A	A	A	A	D	A	A	A	A	A	A	A	D	D	A	A
10	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
11	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
12	A	A	A	A	N	A	A	A	A	A	A	A	N	A	A	A
13	A	A	A	N	A	N	A	A	A	A	A	A	N	A	N	N
14	D	A	A	N	N	N	A	A	A	A	A	A	N	A	D	A
15	A	A	A	A	N	A	A	A	N	N	A	A	A	A	A	A
16	A	A	A	A	A	A	A	A	A	A	A	A	A	A	N	A
17	A	A	A	A	A	A	A	A	A	A	A	A	A	A	N	N
18	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
19	D	A	A	A	N	N	N	N	A	N	A	A	N	D	N	D
20	A	A	A	A	A	A	A	A	A	N	A	A	A	A	N	N
21	A	N	A	A	A	A	A	A	A	A	A	A	A	A	A	A
22	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	D
23	A	A	A	A	N	A	A	A	A	A	A	A	D	N	D	A

Note. A; Agree. D; Disagree. N; No opinion

Participants	Cc1	Cc2	Cc3	Cc4	Ct1	Ct2	Ct3	Ct4	Ct5	Cs1	Cs2	Cs3	Cs4	Cf1	Cf2	Cf3	Cf4
1	D	D	N	A	A	D	A	N	D	N	N	A	N	N	N	N	N
2	D	A	A	D	A	A	A	A	D	D	D	D	D	A	D	A	A
3	D	A	D	D	D	D	A	D	D	D	D	D	D	A	D	N	A
4	D	A	A	D	N	A	D	A	D	A	D	D	D	A	D	D	N
5	A	A	A	A	D	A	A	A	A	A	D	D	A	A	A	A	A
6	A	A	A	A	N	A	A	N	A	A	N	N	A	A	A	A	A
7	A	A	A	D	A	A	A	A	D	D	D	D	D	A	A	A	A
8	A	A	A	A	A	A	A	A	D	D	D	D	N	A	A	A	A
9	D	A	A	A	A	A	D	A	D	D	D	D	N	A	A	A	A
10	A	A	A	A	A	A	A	A	A	A	D	D	D	A	A	A	A
11	N	A	A	D	A	A	A	D	A	D	D	A	A	A	D	A	A
12	N	A	A	A	A	A	A	A	D	N	D	D	N	A	A	A	A
13	D	A	A	A	A	D	N	A	D	D	D	N	D	A	A	N	A
14	A	A	A	A	A	A	A	A	A	D	D	D	N	A	D	A	A
15	D	N	A	A	A	A	A	A	A	A	N	D	N	A	A	A	A
16	D	N	A	A	A	A	A	A	D	D	D	D	D	N	N	N	A
17	A	A	A	A	A	A	A	A	D	N	D	D	D	D	D	N	D
18	D	A	A	D	A	A	A	A	D	D	D	D	D	D	A	D	N
19	N	A	A	A	A	A	A	A	A	N	N	N	N	N	D	N	A
20	A	A	A	N	A	A	A	A	A	N	N	N	A	N	D	A	A
21	A	A	A	D	D	A	A	A	D	D	D	D	D	A	A	D	A
22	D	A	A	D	A	A	A	A	D	D	D	D	D	D	D	A	A
23	A	A	A	A	A	A	A	A	A	N	D	D	D	A	A	N	A

Note. A; Agree. D; Disagree. N; No opinion