EXAMINING INTERNATIONAL BACCALAUREATE DIPLOMA PROGRAMME MATHEMATICS TEACHERS' CONCEPTION OF INTERDISCIPLINARITY AND THEIR TEACHING APPROACH

by

Simge Akbal

B.S., Teaching Mathematics, Boğaziçi University, 2021

Submitted to the Institute for Graduate Studies in
Science and Engineering in partial fulfillment of
the requirements for the degree of
Master of Science

Graduate Program in Secondary School Science and Mathematics Education

Boğaziçi University

2024

to my brother

ACKNOWLEDGEMENTS

I am deeply indebted to numerous individuals whose support and guidance have been invaluable in the completion of this thesis.

First and foremost, I express my profound gratitude to my thesis supervisor Assoc. Prof. Fatma Aslan-Tutak whose expertise, patience, and unwavering support have been instrumental throughout this research journey. Her guidance, encouragement, and support throughout this study. Her expertise and feedback taught me a lot and helped me complete this research. She always offered me unwavering support and increased my motivation for my thesis.

I would also like to thank my committee members Assist. Prof. Yeşim İmamoğlu and Assist. Prof. Armağan Ateşkan for valuable feedback and suggestions. Their insightful feedback, constructive criticism, and encouragement have not only shaped the direction of this thesis but also enhanced my understanding of the subject matter.

I am especially grateful to all the participants in my study. Their willingness to share their experiences has been invaluable to my research and has helped to make this thesis a success. Thank you for your time and contribution.

I extend heartfelt thanks to my family for their unconditional love, unwavering belief in my abilities, and constant encouragement throughout my academic pursuits. Their sacrifices and understanding during challenging times have been a source of strength and motivation. I am indebted to my friends Ayşe Nur Kadan and Deniz Karaaslan who provided valuable insights, support, and encouragement during this demanding yet fulfilling academic journey. Their friendship and camaraderie have made this experience more enjoyable and meaningful.

ABSTRACT

EXAMINING INTERNATIONAL BACCALAUREATE DIPLOMA PROGRAMME MATHEMATICS TEACHERS' CONCEPTION OF INTERDISCIPLINARITY AND THEIR TEACHING APPROACH

The primary purpose of this study was to investigate the manner in which teachers utilizing the International Baccalaureate Diploma Programme integrate interdisciplinarity while teaching exponential functions in mathematics and the assessment process of the Internal Assessment and Extended Essay. Qualitative data were gathered through semi-structured interviews. The first semi-structured interview was conducted with eight teachers from Istanbul to understand their general conceptions about interdisciplinarity and International Baccalaureate Diploma Programme. The second semi-structured was conducted with four teachers who were chosen among the first group to understand their instruction and assessment processes. The interviews were analyzed with two approaches, (i) coding for teachers' conceptions of interdisciplinarity about instruction and assessment and (ii) thematic analysis. Curriculum, interdisciplinary thinking, and implementation of interdisciplinarity appeared in the first analysis of eight teachers. Modelling, conceptual understanding and procedural fluency, nature of school, and requirement of assessment in International Baccalaureate Diploma Programme curriculum appeared in the second analysis of four teachers. In addition, thematic analysis revealed teachers' conceptions of interdisciplinarity in relation with the IB-DP curriculum. Finally, the study found that teachers are becoming interdisciplinary level for the instruction process and interdisciplinary level for the assessment process.

ÖZET

ULUSLARARASI BAKALORYA DİPLOMA PROGRAMI MATEMATİK ÖĞRETMENLERİN DİSİPLİNLERARASI ANLAYIŞLARI VE ÖĞRETİM YAKLAŞIMLARININ İNCELENMESİ

Bu çalışmanın temel amacı, Uluslarası Bakalorya Diploma Programını kullanan matematik öğretmenlerin disiplinlerarasılığı üstel fonksiyonları öğretirken ve İç Değerlendirme ve Genişletilmiş Kompozisyon değerlendirme süreçlerinde nasıl entegre ettiklerini araştırmaktır. Nitel veriler yarı yapılandırılmış görüşmeler yoluyla toplanmıştır. İlk yarı yapılandırılmış görüşme, disiplinlerarasılık ve Uluslarası Bakalorya Diploma Programı hakkındaki genel anlayışlarını anlamak amacıyla İstanbul'da çalışan sekiz öğretmenle gerçekleştirilmiştir. İkinci yarı yapılandırılmış görüşme ise öğretim ve değerlendirme süreçlerinde disiplinlerarasılığı nasıl entegre ettiklerini anlamak amacıyla ilk gruptan seçilen dört öğretmenle gerçekleştirilmiştir. Görüşmeler (i) öğretmenlerin öğretim ve değerlendirmeye ilişkin disiplinlerarasılık anlayışlarının kodlanması ve (ii) tematik analiz olmak üzere iki yaklaşımla analiz edilmiştir. Sekiz öğretmen ile yapılan ilk analizde müfredat, disiplinlerarası düşünme ve disiplinlerarasılığın uygulanması öne çıkmıştır. Modelleme, kavramsal anlama ve prosedürel akıcılık, okulun doğası ve Uluslarası Bakalorya Diploma Programını müfredatında değerlendirme gerekliliği dört öğretmenle yapılan ikinci analizde ortaya çıkmıştır. Buna ek olarak, tematik analiz öğretmenlerin Uluslarası Bakalorya Diploma Programını müfredatı ile ilişkili olarak disiplinlerarasılık anlayışlarını ortaya koymuştur. Son olarak, çalışma öğretmenlerin öğretim süreci için disiplinlerarası hale gelme seviyesinde ve değerlendirme süreci için disiplinlerarası seviyede ortaya koymuştur.

TABLE OF CONTENTS

ACKNOWLEDGEMENTS iv
ABSTRACT v
ÖZET vi
LIST OF FIGURES x
LIST OF TABLES xi
LIST OF ACRONYMS/ABBREVIATIONS xii
1. INTRODUCTION 1
2. REVIEW OF THE LITERATURE 2
2.1. Interdisciplinary Thinking and Learning 2
2.1.1. Interdisciplinarity 3
2.2. Interdisciplinary Thinking 5
2.3. Developing Interdisciplinary Thinking in Educational Settings 6
2.4. Interdisciplinary Curriculum 10
2.5. International Baccalaureate Curricula 12
2.5.1. International Baccalaureate Primary Years Programme (IB-PYP) 13
2.5.2. International Baccalaureate Middle Years Programme (IB-MYP) 13
2.5.3. International Baccalaureate Career-Related Programme (IB-CR) 14
2.5.4. International Baccalaureate Diploma Programme (IB-DP) . . . 14
2.5.4.1. The Core Part of IB-DP 14
2.5.4.2. The Six Groups of IB-DP 15
2.5.4.3. The Learner Profile IB-DP 15
2.5.4.4. Assessment in IB-DP 16
2.5.4.5. Internal Assessment (IA) 17
2.5.4.6. Extended Essay (EE) 18
2.5.4.7. External Assessment 18
2.6. Interdisciplinarity in International Baccalaureate Diploma Programme . 20
2.6.1. Curriculum Components 21
2.6.2. From Principles into Practice 21

2.6.3. Subject Documentation 22
2.6.4. Definition of Interdisciplinary in IB-DP 23
2.7. Teaching Exponential Function 23
2.7.1. Exponential Function in IB-DP 24
2.8. Williams and Roth's Model of Interdisciplinarity 25
3. SIGNIFICANCE OF THE STUDY 28
4. STATEMENT OF THE PROBLEM 30
4.1. Variables 30
4.2. Research Questions 30
5. METHODOLOGY 31
5.1. Research Design 31
5.2. Participants 32
5.3. Data Collection 35
5.3.1. Semi-Structured Interviews 35
5.3.2. Artifact Analysis 37
5.4. Data Analysis 37
5.5. Role of the Researcher 41
5.6. Validity, Reliability, and Trustworthiness 42
5.7. Ethical Considerations 43
6. FINDINGS 44
6.1. Turkish Mathematics IB-DP Teachers' General Conceptions About IB-DP 45
6.1.1. Curriculum 45
6.1.2. Interdisciplinary Thinking 47
6.1.3. Implementation of Interdisciplinary 48
6.1.3.1. Arda's Instruction and Assessment 48
6.1.3.2. Ece's Instruction and Assessment 48
6.1.3.3. Elif's Instruction and Assessment 49
6.1.3.4. Efe's Instruction and Assessment 49
6.1.3.5. Buket's Instruction and Assessment 49
6.1.3.6. Ceren's Instruction and Assessment 49

6.1.3.7. Eren's Instruction and Assessment 50
6.1.3.8. Nil's Instruction and Assessment 50
6.2. IB-DP Mathematics Teachers' Interdisciplinarity Conceptions for Instruction and Assessment 51
6.2.1. Instruction 51
6.2.1.1. Modelling 52
6.2.1.2. Conceptual Understanding and Procedural Fluency . . 53
6.2.1.3. Nature and Culture of School 57
6.2.2. Assessment 58
6.2.2.1. Requirements of the IB-DP curriculum 59
7. DISCUSSION 62
7.1. Influence of Curriculum 62
7.1.1. Intended and Enacted Curriculum 62
7.1.2. Influence of Cultural Aspects 65
7.2. Influence of Instructional Approaches 66
7.3. Influence on Assessment Approaches 69
8. LIMITATIONS AND SUGGESTION 73
REFERENCES 75
APPENDIX A: FIRST LEVEL OF SEMI-STRUCTURED INTERVIEWS . . 85
APPENDIX B: SECOND LEVEL OF SEMI-STRUCTURED INTERVIEWS . 86
APPENDIX C: INSTITUTIONAL ETHICAL APPROVAL FROM BOGAZICI UNIVERSITY 87
APPENDIX D: INFORMED CONSENT FORM 88

LIST OF FIGURES

Figure 2.1. A comprehensive meta-cycle of interdisciplinary inquiry. 27

Figure 6.1. Lecture material of Nil teacher. 54

Figure 6.2. Lecture material of Nil teacher. 55

Figure 6.3. Lecture material of Eren teacher. 56

Figure 6.4. Lecture material of Eren teacher. 56

Figure C.1. Ethics committee. 87

LIST OF TABLES

Table 5.1. Demographic information of participants. 34

Table 5.2. First level of interviews. 38

Table 5.3. Second level of interviews. 39

LIST OF ACRONYMS/ABBREVIATIONS

A and A	Analysis and Approaches
A and A-HL	Analysis and Approaches Higher Level
A and A-SL	Analysis and Approaches Standard Level
A and I	Applications and Interpretations
AP	Advanced Placement
ATL	Approaches to Learning
ATT	Approaches to Teaching
CAS	Creativity, Action, Service
CR	Career-Related
DP	Diploma Programme
EE	Extended Essay
FPIP	From Principles into Practice
GPA	Grade Point Average
HL	Higher Level
IA	Internal Assessment
IB	International Baccalaureate
IB-CR	International Baccalaureate Career-Related
IB-DP	International Baccalaureate Diploma Programme
IB-MYP	International Baccalaureate Middle Years Programme
IBO	International Baccalaureate Organization
IB-PYP	International Baccalaureate Primary Years Programme
ICME	Interdisciplinary Mathematics Education
IGCSE	International General Certificate of Secondary Education
LP	Learner Profile
MoNE	Ministry of National Education
MYP	Middle Years Programme
NCTM	National Council of Teachers of Mathematics
NSF	National Science Foundation

NSES	National Science Education Standards
OECD	Organisation for Economic Co-Operation and Development
PYP	Primary Years Programme
SL	Standard Level
STEAM	Science, Technology, Engineering, Art, and Mathematics
STEM	Science, Technology, Engineering, and Mathematics
TOK	Theory of Knowledge

1. INTRODUCTION

According to the OECD Learning Compass, 21st-century education shapes students' knowledge, skills, attitudes, and values (OECD Future of Education and Skills 2030, 2020, p.8). Four main categories of knowledge are distinguished by the OECD Learning Framework 2030, a byproduct of the OECD Future of Education and Skills 2030 project: disciplinary, interdisciplinary, epistemic, and procedural knowledge. "Interdisciplinary knowledge involves relating the concepts and content of one discipline / subject to the concepts and content of other disciplines/subjects" (OECD, 2019, p.4). For this reason, educational curricula adopt an educational approach that includes interdisciplinary knowledge, relating the concepts and content of one discipline and subject to the concepts and content of other disciplines and subjects. The International Baccalaureate Diploma Programme (IB-DP) is a curriculum that adopts and applies this approach. The International Baccalaureate Diploma Program (IB-DP) is an educational program that aims to cultivate inquiring, knowledgeable, and caring young people who contribute to the creation of a more peaceful and just world through intercultural understanding and respect. In this consideration, the perspective of IB-DP resources aims to explore the nature of International Baccalaureate resources in order to gain a comprehensive understanding of how interdisciplinarity is organized in all International Baccalaureate (IB) programs (IBO, 2021). Also, throughout the cross-program documentation of IB, interdisciplinarity is articulated as a component of the broader IB educational ethos (IBO, 2021). The primary purpose of the current study is to understand, interdisciplinary (interdisciplinarity) conceptions of International Baccalaureate Diploma Program (IB-DP) mathematics teachers in Turkey while instruction and assessment processes. The study used the multiple case study design to investigate the research questions. The study was conducted with International Baccalaureate Diploma Program mathematics teachers who work at different state and private schools in Istanbul, Turkey.

2. REVIEW OF THE LITERATURE

2.1. Interdisciplinary Thinking and Learning

Throughout history, as time goes the way of life of people has changed from a few individuals to tribes, from tribes to unrelated environmental communities, and from unrelated environmental communities to integrated environmental societies. Living in an integrated environmental society has brought people to being in a common shared life. So, they have started to share a common environment within communication and shared aims.

According to Hotăran

> "The silo effect is a phrase that is currently popular in the business and organizational communities to describe a lack of communication and common goals between departments in an organization. The silo effect gets its name from the farm storage silo, probably because there could be two silos right next to each other and if people were inside them, they could not be able to communicate, since silos are tall, narrow buildings with no windows and are even supposed to be airtight" (2009, p.216).

It is obvious silo effect phrase refers that there is no common environmental integration between silos which means that there is no shared culture between them. To make this a common environment, they benefit from science with each discipline. With the novelty of each discipline, they have started to perceive the world better economy, mathematics, health, etc. If we consider each silo as a discipline in an integrated well-designed environmental society, these silos should share a common culture and values of the society. However, in a society, there is an environment that consists of integration between each discipline that takes a part in society. Integrating means that a discipline should adjust to each discipline to be a part of a social network and take steps so that other disciplines can adjust to their roles. If this integrated environmental society is seen as an integration between disciplines, then each discipline shares an intersection between them in this environment. From here, the silo effect phrase can

be seen as opposed to the integration of more than one discipline which is named as interdisciplinary. The latter refers to the integration of more than one discipline. To be able to understand what is interdisciplinary it is needed to look at its definition of interdisciplinary research, interdisciplinary knowledge, and interdisciplinary educational perspectives.

2.1.1. Interdisciplinarity

The different fruits can be served alongside one another, cut up and served as a fruit salad, or carefully mixed so that the particular flavors of each are lost and the smoothie is created as a result. In mind, be aware that the combined rate has nothing to do with quality; in some situations, a simple strawberry or an apple would outperform all smoothies, while in others, only a fruit salad will suffice. Here, fruit salad can be considered as more than one discipline together, however, the creation of a smoothie by using more than one distinct fruit can be regarded as interdisciplinarity or interdisciplinary. "Interdisciplinarity or interdisciplinary studies involves the combination of two or more academic disciplines. Interdisciplinarity involves bringing together distinctive components of two or more disciplines" (Nissani, 1995, p.121). Multidisciplinary, interdisciplinary, and transdisciplinary are described as the degree of integration of various knowledge sources according to a progressive scale developed by the Amsterdam Institute for Interdisciplinary Research. Each field provides a piece of the jigsaw in interdisciplinary research investigations. Nevertheless, neither the study method nor the results themselves include this. The end result is a parallel view of a certain issue from many discipline angles. While creating a solution, interdisciplinary working practices really incorporate working techniques and solutions at every stage. Beyond the expertise of trained professionals and scientists, transdisciplinary research incorporates common knowledge to produce novel, creative answers (Klassen, 2018). Interdisciplinarity often refers to four areas in academic discourse for Nissani (1995) it is called "Four Interdisciplinary Realms": knowledge, research, education, and theory which is applied in academic discourse.

Everything starts with a problem and the aim of the disciplines is to find a proper solution for this current problem. If one discipline is not enough to find this solution to create fresh uses and expressions, then the usage of more than one discipline is required for the solution of a problem which is called an *interdisciplinary problem.* In order to develop new applications and expressions, *interdisciplinary research* is seen as the merging of unique elements of more than one disciplinary subject in the search for fresh perspectives, useful uses, or artistic expressions corporately. According to Brown (2022), the mathematical modelling of financial markets falls under the umbrella of applied mathematics is called financial mathematics. It is an interdisciplinary research area combining both finance and mathematics to find proper methods to solve given problems that cannot be solved by mathematics and finance, separately. So, a problem of financial mathematics is an example of an interdisciplinary problem. A financial mathematics researcher would solve problems which require interdisciplinary skills and knowledge. In other words, it is needed to have a proper solution for the mathematical modelling of financial markets. Moreover, it can be said that if there is more than one discipline utilizing by using a particular knowledge then it can be called interdisciplinary knowledge. When researchers try to solve an interdisciplinary problem, they rely on knowledge from all the related disciplines which in turn provides researchers to learn from other disciplines. If researchers prepare mathematical modelling that consists of both mathematics and finance, they need to look at the benefits of both mathematics and finance by integrating their knowledge of them to reach a mathematical model. "Interdisciplinary knowledge is necessary, but it is insufficient to ensure the condition for interdisciplinary research which is combining distinctive components of two or more disciplines while searching or producing new knowledge, operational procedures, or artistic expressions" (Nissani, 1995, p.123). This means that while interdisciplinary knowledge is necessary to conduct any interdisciplinary research, the outcome of such research also provides new interdisciplinary knowledge which may evolve into new problems to solve. After a defined period of time, the interdisciplinary problem, intervention, and/or implementation strategies continue to be delivered, and/or interdisciplinary knowledge has been maintained with interdisciplinary research. An interdisciplinary problem may evolve or adapt while continuing

to produce benefits for interdisciplinary (Moore *et al.*, 2017). This means that interdisciplinary knowledge is flexible. This flexibility turns out to an evolutionary if the ability to combine information from several fields to develop significant relationships.

2.2. Interdisciplinary Thinking

According to Goldman *et al.* (2009),

> "Working in mathematics, physics, and technology reveals that design thinking abilities might really help children in basic academic subjects as well as develop the cognitive and social abilities of middle school students. The description of thinking as a method for original problem-solving establishes a direct and dynamic link between action and thought. Thinking has the ability to influence how well people acquire abilities including cooperating in groups, adhering to procedures, identifying issues, and coming up with solutions" (p.39).

For this, interdisciplinary thinking is really important for the integration of mathematics, science, and technology. In interdisciplinary higher education, the name given to the ability to integrate or synthesize knowledge of disciplines is "interdisciplinary thinking" or" interdisciplinary understanding" (Spelt *et al.*, 2015). The designs used in interdisciplinary higher education are, by way of example, short-term training sessions, mid-term courses, and long-term curricula. Other aspects of the designs that differ from approach to approach are, for instance, the instructional strategies teachers use and the disciplines' roles (Spelt *et al.*, 2015). Outcome-based pedagogical approach model (Biggs and Tang, 2011) may help teachers design consistent interdisciplinary learning environments. It may help students understand what is expected from them in those learning environments to think interdisciplinary by considering sub-categories: personal characteristics, prior experiences, teacher, pedagogy, learning process pattern, learning activities, and assessment (Spelt *et al.*, 2015). For example, interdisciplinary thinking includes "Design thinking, combined with scientific and technological thinking, allows us to explore the new frontier of design and innovation and to link design to the future through achieving the balance of desirability, possibility, and feasibility" (Lou and Ma, 2015). The vertical core competencies are less important in the "T-shaped" or" hybrid" educational paradigm than in the horizontal transdisciplinary or

linked fields. At the moment, Science, Technology, Engineering, and Math (STEM) are the cornerstones of our educational directives, and there are many crossovers from one field to another to support the "T-shaped" model, which depends on each other for implementation but also provides a depth of vertical domains for students to explore (Nae, 2017). From here, STEM is seen as a part of interdisciplinary studies because in STEM there are interdisciplinary studies between science, mathematics, engineering, and technology which are separate disciplines. All combination of them makes interdisciplinary studies, and thinking in STEM-related knowledge requires interdisciplinary thinking.

According to Spelt *et al.*, (2009), "Interdisciplinary thinking was defined as the capacity to integrate the knowledge of two or more disciplines to produce a cognitive advancement in ways that would have been impossible or unlikely through single disciplinary means" (p.365). Based on this definition, interdisciplinary thinking can be considered a complex cognitive skill with a number of subskills such as the ability to change disciplinary perspectives and create meaningful connections within and across disciplines. Interdisciplinary thinking does not occur spontaneously, the process takes time for people to achieve enough level of expertise in its practice. In addition, people need help to be able to synthesize and connect two or more disciplines. For this interdisciplinary thinking is required. As a result of this, the blending of knowledge enables the integration of disciplinary knowledge. This situation allows an advance in understanding, for instance, a conceptual model that demonstrates the application of factors derived from different disciplines by enabling their thing in an interdisciplinary way (Spelt *et al.*, 2015).

2.3. Developing Interdisciplinary Thinking in Educational Settings

From an educational perspective, education is an environment with the integration of enriching experiences as an individual and as a community. This means that in a learning environment, there is an environmental community if the environment is created in a school setting that will be a classroom with different insiders which

are a teacher and students. In this community, there are relationships to ensure environmental integration. NSF graduate education model (National Science Foundation, 2006) program's goal was to integrate teaching and learning through sustained, systematic interactions between graduate research scientists and K-12 teachers in the context of the K-12 classroom. Teachers would gain experience in explaining new scientific ideas to their students, and students would receive additional mentoring from a diverse functionary of research scientists in the classroom by combining more than one discipline (Dyehouse *et al.*, 2009). It is obvious that the K-12 program's focus is on bringing about change in the relationships among teachers, fellows, and students in order to generate change and achieve the program's objective, which entails thinking interdisciplinarily. It is clear that one of the main components of learning enriches the importance of relationships between these environmental community parts which are teacher and student, student and topic, and teacher and topic under the curriculum.

In the 1990s, practically all national reform initiatives emphasized the importance of integrating or connecting the curriculum. Integration of subject matter helps students develop critical thinking skills and a shared knowledge base essential for success in the twenty-first century. For this reason, curricular integration is effective in fostering students' development of deeper understandings, ability to perceive the "big picture", relevance of the curriculum to students, links between key ideas, and motivation for learning (Czerniak *et al.*, 1999). Therefore, when new information and abilities are integrated into context and students develop connections between concepts, meaningful learning happens. As time goes this integration in the curriculum for education takes the name "interdisciplinary education".

Students are thought to benefit from a thematic approach to mathematics instruction because it may build on their real-world knowledge and experiences and improve cognitive and emotional performance. While teaching in subjects primarily emphasizes mathematical information, teaching mathematics thematically emphasizes the usage of applications of mathematics around a primary theme. "For example, if the central theme is sports, the thematic unit would be organized in different content areas such

as percentages, measurement, statistics or algebra, and in all these areas sport-related applications of mathematics will be emphasized" (Handal and Bobis, 2004, p.3). This integration model is associated with constructivist ideas of learning mathematics due to their shared premise for building mathematical knowledge within those contexts (Handal and Bobis, 2004). As all learning is placed by definition, contextualizing teaching is at the heart of situated learning. According to Clancey, 1995, "The theory of situated learning claims that every idea and human action is a generalization, adapted to the ongoing environment, because what people see and what they do arise together. From this perspective, thinking is a physical skill" (p.1). So, situated learning is used for all types of learning. Here, it can be said that interdisciplinary learning is an arm of situated learning. The reason for this is that interdisciplinary learning is an integration model that requires thinking deeply to create knowledge properly. Interdisciplinary learning enables learners to make generalizations for complex ideas by using knowledge that comes from integration of more than one discipline by thinking interdisciplinary.

In most of developed countries, the objective is to run an ongoing operation, properly functioning in a better way, in education, whereas the educational system is a system in the making in developing countries. To determine future priorities in terms of present demands, the development process necessitates thorough planning for education that involves all social structures of a country, including its people, society, and culture. This is called a holistic theme for education. In essence, holistic education aims to create a building. In holistic education, knowledge and skills develop as by-products of reflecting and acting on a real-world experience rather than on a carefully constructed reality (D'Ambrosio, 1981). So, from the standpoint of interdisciplinary studies, one of its key goals is to construct a structure by including people, society, and culture through the integration of other disciplines. A combination of disciplinary knowledge and approaches that offers a more comprehensive understanding is interdisciplinarity (Knight *et al.*, 2013). For a developed holistic educational approach, interdisciplinary education can be defined as integrating more than one distinct discipline while applying a curriculum in an instructional program. So, teaching how to prepare the mathematical modelling that is interrelated with both mathematics and

finance and a combination of them. Interdisciplinary studies combine techniques and ideas from a number of well-known disciplines or recognized academic sectors of an education perspective which is applied by researchers, students, and teachers. "So, at any given historical period, the interdisciplinary richness of any two exemplars of knowledge, research, and education can be compared by weighing four variables: number of disciplines, the distance between them, novelty, and integration" (Nissani, 1995, p.121).

It is considered that a cross-disciplinary approach fosters holistic knowledge of interdisciplinarity can help to handle today's complicated concerns. This idea has resulted in an increase in interest in interdisciplinary higher education throughout the years. In contrast to traditional higher education, which focuses on domain-specific knowledge and the development of broad abilities, this type of higher education attempts to promote boundary-crossing talents. The capacity to alter viewpoints, combine information from other areas, and deal with complexity are examples of boundary-crossing talents (Spelt *et al.*, 2009).

Interdisciplinary studies are applied at all levels of education to prepare new generations for interdisciplinary thinking. The way is to adapt and apply interdisciplinary education by applying a convenient curriculum because the purpose of a curriculum is to foster the students' personalities in terms of a vivid sense and inquiry to promote holistic development, including their physical, intellectual, emotional, social, and spiritual facets. "All too often a curriculum is called interdisciplinary when it is actually multidisciplinary: Multiple perspectives are presented without any support for the integration of disciplinary knowledge throughout the curriculum" (Spelt *et al.*, 2009, p.366).

> "As a consequence, in curricula on food studies, for instance, students lack the ability to integrate the required disciplinary knowledge of food processing and food microbiology to keep bacterial growth within food safety criteria. Specific support and learning tasks intended to develop interdisciplinary thinking appear to be important" (Spelt *et al.*, 2009, p.366).

The components of the student and learning environment (presage level) act as precursors to the learning process, collectively influencing the activities undertaken by students in relation to a given learning task (learning process level). The learning process, in turn, gives rise to the learning outcome of interdisciplinary thinking (product level). (Biggs, 1993).

With the help of interdisciplinary education, each curriculum can have

> "...integration of data, methods, tools, concepts, theories, and/or perspectives from multiple disciplines or bodies of knowledge in order to answer a question, to solve a problem, or to address a topic or theme that is too broad or complex to be dealt with by one discipline" (Klein, 2021, p.xviii).

2.4. Interdisciplinary Curriculum

In education, with curriculum interdisciplinarity is supposed to create faster rates of creativity and promote deeper understandings of multifaceted themes than disciplinary activities because it links together divergent objectives and ways of knowing (Laursen *et al.*, 2022). Therefore, the aim is satisfied by connecting and integrating more than one idea of academic schools, professions, or technology, along with their specific perspectives and procedures to get an enriching common task in environmental integration to get a proper interdisciplinary integrated curriculum. Applying such a curriculum which is integrated with interdisciplinary helps prepare students for the new world which is continuing and developing day by day. By doing that the importance is given to the knowledge that highlights the integration of more than one discipline together. Therefore, new generations will be prepared properly for their future which affects also their integrated environmental society.

> "Those calling for interdisciplinary education have been pressuring the academy to change the way in which it organizes departments, structures curricula, and views knowledge. Because problems of modern-day society have grown in complexity, they argue, interdisciplinary approaches have become necessary to reach effective and innovative solutions.
>
> In response, the undergraduate curricula have broadened to include more programs that take interdisciplinary approaches, presumably promoting students'

> abilities to synthesize and integrate information from different disciplines" (Knight *et al.*, 2013, p.155).

To cultivate a society that is scientifically literate, interdisciplinary science education is essential. It should be required of students to assess and consider arguments pertaining to real-world issues, which are rarely limited to information based solely on science. In order to prepare students to be scientifically literate for K–12 education, the National Science Education Standards (NSES) place a strong emphasis on the integration of math and science. According to the NSES, mathematics comprehension is essential to all facets of scientific investigation, including formulating reasonable assertions in K–12 contexts, obtaining, organizing, and presenting data, and posing questions (Yarker and Park, 2012). Therefore, "It can be expected that yearlong curriculum development is an important part of preparing teachers to use interdisciplinary approaches in the classroom" (p.231). STEM (Science, Technology, Engineering, and Mathematics) education, which is a component of interdisciplinarity in general and mathematics education in particular, can facilitate the preparation of individuals for the challenges of the twenty-first century, including the ability to address socio-scientific issues and engage in responsible research and innovation in the pursuit of ethically acceptable, socially desirable, and sustainable societies. The majority of applications of STEM in real-life and in the world of work are interdisciplinary in nature (Maass *et al.*, 2019). This "reality" provides a strong argument for considering interdisciplinary or integrated approaches to STEM education. Such an approach will need to recognize the interdisciplinary connection of the four STEM subjects as well as how STEM can be linked to other subjects, as Hazelkorn *et al.*, (2015) comment, as follows: "Greater attention should be given to the value of all disciplines and how inter-disciplinarity (STEAM [Science, Technology, Engineering, Art, Mathematics] rather than STEM) can contribute to our understanding and knowledge of scientific principles and solve societal challenges" (p. 9).

STEAM, of which mathematics is a part, is a field that is intertwined with other disciplines, such as physics, chemistry, biology, economics, politics, sociology,

etc. Ernest (2002) suggested that mathematics is a tool for social empowerment essential for making socially just decisions and judgments, that is, for acting as a socially critical citizen:

> "The empowered learner will not only be able to ask and solve mathematical questions (mathematical empowerment), but will also be able to understand and begin to important questions about a wide range of social uses and wide range of social uses and misuses of mathematics (social empowerment)" (p.6).

As outlined by Geiger *et al.*, (2015b), the twenty-first century model of numeracy encompasses a range of key dimensions, including real-world contexts, mathematical knowledge, dispositions towards the use of mathematics, competence with physical, representational, and digital tools, and an evaluative component, namely a critical orientation. This component enables the dimensions of the model to be applied to real-world problems in a coordinated manner, thereby facilitating evidence-based decision-making and judgment. In the context of social engagement or societal issues, this implies that a numerate individual is able to present their own arguments and challenge the positions or claims of others. In conclusion, both numeracy education and the investigation of socio-scientific issues through a modelling approach represent forms of responsible citizenship education. Consequently, the implementation of responsible global citizenship education from one of these educational perspectives can facilitate the advancement of the role of mathematics in educational fields. Therefore, every mathematics curriculum adopts the approach of teaching students with a global understanding and an appreciation for interdisciplinary collaboration. International Baccalaureate programs are designed to provide students with a high-level qualified education that challenges them intellectually and prepares them to become citizens of the world.

2.5. International Baccalaureate Curricula

The International Baccalaureate (IB) offers a comprehensive range of international educational programs for students aged 3 to 19. These programs are designed to challenge students intellectually and to provide them with a high-quality education.

There are four distinct IB programs: the Primary Years Program, the Middle Years Program, the Career-related Program, and the Diploma Program.

2.5.1. International Baccalaureate Primary Years Programme (IB-PYP)

The Primary Years Programme provides a transdisciplinary, inquiry-based curricular structure that strengthens conceptual knowledge. It is a method of teaching for students ages 3 through 12 that is focused on them. It showcases the greatest in educational research, thought leadership, and IB World School experience. The PYP has developed into a global leader in education with an eye toward the future. The PYP, which adapts to the possibilities and problems faced by young pupils in a world that is changing quickly, is a model of the greatest educational practices in the world. The fundamental tenet of the PYP curricular structure is that students are collaborators and agents of their own education. It puts a high value on people and their interactions in order to create a vibrant learning environment. PYP students exercise the initiative to own and take charge of their education. PYP students gain the information, conceptual understandings, abilities, and characteristics of the IB Learner profile necessary to make a difference in their own lives, the lives of those around them, and beyond via learning through inquiry and reflection on their own learning (IBO, 2023).

2.5.2. International Baccalaureate Middle Years Programme (IB-MYP)

In order to prepare them for success in both future education and in life, the Middle Years Programme (MYP) encourages students, ages 11 to 16, to draw practical links between their academic work and real-world experiences. The MYP seeks to cultivate globally minded youth with active learning skills who can relate to others and lead meaningful lives. The curriculum gives students the freedom to research a variety of important topics that are relevant on a local, national, and international level. Young individuals who are critical, creative, and thoughtful thinkers are the end product (IBO, 2023).

2.5.3. International Baccalaureate Career-Related Programme (IB-CR)

CR students are required to complete a minimum of two IB Diploma Programme (DP) courses. These courses comprise a core consisting of four components and a career-related study. The DP courses provide the theoretical underpinning and academic rigour of the programme. The career-related study further supports the programme's academic strength by providing practical, real-world approaches to learning. The CP core helps students to develop the skills and competencies required for lifelong learning (IBO, 2023).

2.5.4. International Baccalaureate Diploma Programme (IB-DP)

The Diploma Programme was created to give students a well-rounded education, ease cultural and geographic mobility, and advance global knowledge for students who are aged between 16 and 19. IB-DP has a core part that includes Extended Essay (EE), Theory of Knowledge (TOK), and Creativity, Activity and service (CAS) and six groups which are Studies in Language and Literature, Language acquisition, Individuals and Societies, Sciences, Mathematics, and Arts. (IBO, 2023)

2.5.4.1. The Core Part of IB-DP. The IB-DP is distinctive for a variety of reasons, one of which is its emphasis on three essential elements that go beyond content acquisition for the core part. The first is an assignment known as the Extended Essay (EE), which gives students the chance to explore a subject of particular interest and familiarizes them with the independent research and writing abilities required at universities (IBO, 2018). The EE "offers students the opportunity to engage in personal research on a topic of their own choice, under the supervision of a supervisor" (IBO, 2018), in addition to encouraging intellectual exploration and audacious innovation. Hence, an Extended Essay allows students in-depth studies in a discipline. Thus, after completing this study, students become deeply knowledgeable in the discipline they study.

The Theory of Knowledge (TOK) course, the second fundamental element of the DP, is "designed to develop a coherent approach to learning that transcends and unifies the academic areas and encourages appreciation of other cultural perspectives" (IBO, 2023). The TOK course asks students to reflect on the effects of cultural change and global issues as well as to think critically about what they encounter while taking other viewpoints into account (IBO, 2023).

Creativity, Action, and Service (CAS), the third core element that is exclusive to the IB, is the centerpiece of the Diploma Programme and runs concurrently with the academic courses. It consists of artistic pursuits, creative problem-solving, physical activity that promotes a healthy lifestyle, and volunteer work in the community that benefits the student's learning (IBO, 2023). In local, national, and worldwide contexts, CAS promotes students to participate as a team in activities and actions (IBO, 2023).

2.5.4.2. The Six Groups of IB-DP. There will be topics taken at standard level (SL) and subjects at higher level (HL) for the students. Although the breadth of HL and SL courses varies, they are assessed using the same grade descriptions, and students are expected to show a higher level of knowledge, comprehension, and abilities from the groups Studies in Language and Literature, Language acquisition, Individuals and Societies, Sciences, Mathematics, and Arts. Literature and performance from the group Studies in language and literature, Language and culture from the group Individuals and societies, Environmental systems and societies from the group Sciences are Interdisciplinary subjects explicitly in the IB-DP curriculum (IBO, 2023).

Every student enrolls in a minimum of three higher-level topics and a maximum of four standard-level subjects. Subjects at the standard level require 150 teaching hours and there are 240 teaching hours at the higher level (IBO, 2023).

2.5.4.3. The Learner Profile IB-DP. All IB programmes seek to cultivate globally aware individuals who, acknowledging their shared humanity and responsibility for the earth,

contribute to building a more just and peaceful world (IBO, 2021). The profile aims to develop learners who are inquirers, knowledgeable, thinkers, communicators, principled, open-minded, caring, risk-takers, balanced, reflective, and attributers.

2.5.4.4. Assessment in IB-DP. Every IB programme is founded on a constructivist theory of how students learn. Constructivism is a theory of cognition that is now widely used and accepted and claims that knowledge is actively constructed rather than passively acquired. It refers to methods that acknowledge the significance of engaging and challenging learners' preexisting mental models in order to improve understanding and performance. IB programmes are made to encourage young people to be intellectually curious and give them the knowledge, conceptual understanding, skills, reflective practices, and attitudes necessary to become independent lifelong learners in the context of a constructivist approach to teaching and learning (Hill and Saxton, 2014). All the programs were designed to foster intellectual curiosity and provide young people with the knowledge, conceptual understanding, skills, reflective practices, and attitudes necessary to become independent lifelong learners. To achieve this goal, it is essential to implement high-quality assessment types.

For the assessment part of IB-DP students obtain grades in the DP on a scale of 7 to 1, with 7 being the highest. A grade is given to students for each DP course they attempt. The sum of a student's final diploma result scores for all subjects is their final score. Students who achieve at least 24 points, subject to a certain minimal performance requirement, such as passing the three DP core requirements, will get the IB-DP diploma. The DP assessment procedures evaluate the extent to which students have acquired advanced academic skills in fulfilling the aforementioned goals. These skills include the ability to analyze and present information, evaluate and construct arguments, and solve problems in a creative manner. In addition to these advanced skills, the assessment also gauges the acquisition of fundamental abilities, such as the ability to retain knowledge, comprehend key concepts, and apply standard methods. Furthermore, the assessment encourages an international outlook and intercultural skills, where appropriate.

2.5.4.5. Internal Assessment (IA). Internal assessment is an essential component of the course and is mandatory for both SL and HL students. It enables students to demonstrate the application of their skills and knowledge and to pursue their personal interests without the time limitations and other constraints that are associated with written examinations. The internal assessment should, to the extent possible, be integrated into normal classroom teaching and not be a separate activity conducted after a course has been taught. The internal assessment requirements at SL and HL is individual explorations. This is a written assignment that requires the student to investigate a specific area of mathematics. Students may select from many activities, including modelling, investigations, and applications of mathematics. To assist teachers and students in the selection of a topic, a list of stimuli is provided in the teacher support material. However, students are not constrained to this list. The exploration should be approximately 12-20 pages in length, with double line spacing, including diagrams and graphs, but excluding the bibliography. However, the quality of the mathematical writing is of greater importance than its length. It is the responsibility of the teacher to provide guidance at all stages of the exploration. This guidance should include directing students towards more productive routes of inquiry, suggesting suitable sources of information, and offering advice on the content and clarity of the exploration in the writing-up stage. Teachers are responsible for indicating to students the existence of errors but should not explicitly correct these errors. It is imperative that students consult with their instructors throughout the process (IBO, 2021).

For the purpose of internal assessment, a number of assessment criteria have been identified. It is evaluated according to five assessment criteria. Each assessment criterion is accompanied by level descriptors, which describe specific achievement levels and include an appropriate range of marks. The level descriptors concentrate on positive achievement, although for the lower levels, failure to achieve may be included in the description. Teachers must judge the internally assessed work at SL and at HL against the criteria using the level descriptors. The assessment criteria A to D are the same for both SL and HL. The fifth criterion, “Use of Mathematics”, differs between SL and HL (IBO, 2021).

2.5.4.6. Extended Essay (EE). The extended essay provides IB-DP students with practical preparation for a mini-research. It offers students the opportunity to research a topic of personal interest related to one of their six DP courses or to pursue an interdisciplinary approach to the World Studies extended essay. Through the process of research for the extended essay, students develop the following skills: formulating an appropriate research question, making a personal discovery about the topic, communicating ideas, and developing an argument. The process of writing an extended essay develops the capacity to analyze, synthesize, and evaluate information. An extended essay can also be written in the context of world studies, where students conduct an in-depth interdisciplinary study between two IB diploma disciplines on a topic of contemporary global significance. (IBO, 2023).

All extended essays are externally assessed by examiners appointed by the IB. The essays are marked on a scale from 0 to 34. The score a student receives is related to a band. The bands are as follows:

(i) A - work of an excellent standard
(ii) B - work of a good standard
(iii) C - work of a satisfactory standard
(iv) D - work of a mediocre standard
(v) E - work of an elementary standard

It is possible to ascertain the extent to which points awarded for the extended essay contribute to a student's overall diploma score (IBO, 2023).

2.5.4.7. External Assessment. The International Baccalaureate (IB) assesses student work as direct evidence of achievement against the stated goals of the Diploma Programme (DP) courses. Consequently, students are required to take written examinations at the conclusion of their IB Diploma Programme courses, which are then marked by external IB examiners.

The six groups of IB-DP have different external assessment statuses for both SL and HL level students. For IB-DP SL students, papers 1 and 2 are externally set and externally marked. Collectively, they contribute 80percent of the final mark for the course. These papers are designed to allow students to demonstrate their knowledge and abilities. Papers 1 and 2 will contain some questions or parts of questions that are similar to those on the HL papers. For paper 1, students are not permitted to use a graphical display calculator, whereas for paper 2, students are allowed to use one. Conversely, for IB-DP HL students, papers 1, 2, and 3 are externally set and externally marked. Collectively, they contribute 80percent of the final mark for the course. These papers are designed to allow students to demonstrate their knowledge and abilities. For paper 1, students are prohibited from utilizing a graphical displayed calculator, whereas for paper 2, this is permitted. Furthermore, paper 3 comprises two mandatory extended-response problem-solving questions, which are exclusive to HL students. It should be noted that not all question parts necessitate the utilization of the graphical display calculator. In total, students can earn up to 80percent of their marks for the mathematics lesson. Regarding the DP core, individual marks are given to the theory of knowledge (TOK) and extended essay (EE) components, which when added together can add up to 3 extra points to the final diploma result. The final component of the DP core, creativity, action, and service (CAS) does not count toward the overall point total, but it is a prerequisite for the diploma to be awarded.

The International Baccalaureate (IB) recognizes achievement in a wide range of subjects, and it reflects this idea by awarding the same number of points for higher-level (HL) and standard-level (SL) courses. Although the scope of HL and SL courses varies, they are evaluated using the same grade descriptions. Students who are taking HL courses are required to exhibit the different components of the grade descriptors over a broader range of knowledge, comprehension, and abilities.

2.6. Interdisciplinarity in International Baccalaureate Diploma Programme

The International Baccalaureate resources aim to investigate the nature of International Baccalaureate resources in order to gain a comprehensive grasp of the way that interdisciplinarity is organized within all IB programmes.

IB resources fall into a number of different categories:

- "Cross-programme" documents.
- From Principles into Practice documents.
- Subject guides.
- "Core" guides.
- Teacher Support Materials and other resources.
- Definitions of interdisciplinarity and the family of related terms.
- "Curriculum components". This includes the teaching and learning curriculum components which are presented in the form of structured frameworks, i.e. the Learner Profile attributes, the Approaches to Teaching principles, and the Approaches to Learning skills" (IBO, 2021, p. 80).

Cross-programme documentation in IB education are listed as "What is an IB Education? Support Material and Programme Standards and Practices". These texts do not have any particular sections devoted to interdisciplinary education. Instead, there is a propensity for the idea of interdisciplinarity to be included in the documents as something relevant to the many aspects of IB programme development, teaching, and assessment (IBO, 2021). The Theory of Knowledge (TOK) course in the DP and the idea of having an open mind to other cultures. In terms of the curriculum, interdisciplinarity is typically described as a way to bring together knowledge from many academic areas. Interdisciplinarity is defined in relation to the TOK course as a strategy for encouraging critical self-awareness in students through an examination of the many techniques of inquiry used by each academic field.

Although in varied degrees, all of the cross-programmed texts often include both explicit and tacit considerations of interdisciplinarity. According to a top-level scoping, the Programme Standards and Practices document appears to include the most explicit and implicit allusions to interdisciplinarity.

> "The concept of interdisciplinarity is incorporated into IB cross-programme documents through explicit or implicit discussions, though without containing specific sections dealing exclusively with interdisciplinary learning. The concept is often related to the different components of planning, teaching, and assessing the IB programme.Throughout cross-programme documentation, interdisciplinarity is articulated as a component of the IB's broader educational ethos. In cross-programme documentation, interdisciplinarity is often associated with concepts such as constructivism, international mindedness, and holistic, inquiry-based, and student-focused learning" (IBO, 2021, p.82).

2.6.1. Curriculum Components

Three important curricular elements for the IB-DP are presented as hierarchical frameworks: The Learner Profile (LP) consists of 10 traits that all students should work to hone. The learning community expects all members to act as role models for these qualities. The Approaches to Teaching (ATT), is a set of six pedagogical tenets that sum up the basic pedagogical ethos underlying all IB programmes. The Approaches to Learning (ATL), consists of five interconnected skill categories. This gives students a foundation for the abilities they should acquire during their education. The individual elements of each of these curriculum components (the LP attributes, the ATT principles, and the ATL skills) will be explored for links to the concept of interdisciplinary learning (IBO, 2021).

2.6.2. From Principles into Practice

As a tool for IB staff that "provides guidance to teaching and learning" (IBO, 2021, p.84). For all programes, the IB From Principles into Practices (FPIP) publications are designed to be used by all IB staff members".The FPIP documents often implicitly refer to interdisciplinarity in relation to the topics of technology, curriculum

planning, connecting communities, language teaching and acquisition, transition between programmes, approaches to teaching and learning, TOK, CAS, and assessment" (IBO, 2021 p.84).

2.6.3. Subject Documentation

Teachers can use the IB topic guide materials as a resource to help with "planning, teaching, and assessment of the subject in schools". The DP guides provide references to subjects that correspond to the individual course's curricular structure. The topic guides frequently make mention of interdisciplinarity as a concept linked to other components of the IB curriculum rather than including separate sections devoted to interdisciplinary learning. Theory of Knowledge (TOK) in the DP, conceptual understanding, curricular design, and coherence are a few issues that are usually linked to interdisciplinarity (IBO, 2021).

> "The parts of the subject guides that appear most likely to mention interdisciplinarity are those which refer to: key concepts and conceptual understanding, links to TOK in the DP, curriculum planning, and occasional sections discussing the allocation of teaching hours and materials". (IBO, 2021, p.85).

To make interdisciplinarity possible, the topic guides may suggest allocating extra teaching hours: "in practice, more time is often necessary to meet subject-group aims and objectives and to provide for the sustained, concurrent teaching that enables interdisciplinary study".

> "An illustrative example of an implicit reference to interdisciplinary learning is found in the DP: Mathematics: Applications and Interpretation Guide. In a subsection of the introduction, one of the stated aims of the mathematics course is to enable students to take action to apply and transfer skills to alternative situations, to other areas of knowledge, and to future developments in their local and global communities" (IBO, 2021, p.85).

2.6.4. Definition of Interdisciplinary in IB-DP

Interdisciplinary approaches are implemented in the DP. The programme's documentation provides a definition of interdisciplinarity according to which interdisciplinary subjects integrate knowledge, tools and skills from different disciplines and study fields. More specifically: "DP defines interdisciplinary courses as those that integrate knowledge, tools and skills from different subject groups" (IBO, 2021, p.90). In order to facilitate students' interdisciplinary understanding, the programme, according to Diploma Programme From Principles into Practice, allows the development of interdisciplinary learning where students can make connections between various academic disciplines and fields of knowledge. Curriculum areas like Theory of Knowledge (TOK) and the Extended Essay include interdisciplinary perspectives that are taught to students. According to Diploma Programme From Principles into Practice

> "Concurrency of learning, which is a vital organizational component of the DP, provides one important means of supporting interdisciplinary learning. Students are expected to make connections between different academic disciplines and not to study subjects in isolation from each other. The possibility to explore similar topics concurrently and to transfer tools or concepts from one subject to another may enable interdisciplinary understanding" (IBO, 2021, p.91).

2.7. Teaching Exponential Function

Mathematical functions represent a significant component of school mathematics curriculum and the topic of function should be imparted with comprehension. Functions constitute an important aspect of school mathematics, being of paramount importance for effective learning and teaching. However, they are perceived as one of the most challenging topics for educators to teach (National Council of Teachers of Mathematics, NCTM, 2010). There is a necessity for learners to grasp the fundamental principles of two functions in order to analyze and interpret problem-solving processes. The interpretation of functions appears to be a significant challenge in the learning of exponential functions. Exponential and logarithmic functions are crucial concepts that play a foundational role in mathematical courses, including calculus,

differential equations, and complex analysis. This has demonstrated the necessity for teachers to teach these functions for understanding, as they are predominantly utilized in real-world scenarios (NCTM, 2010). Mathematical modeling is a phenomenon that occurs in contexts that are seemingly non-mathematical. In such cases, it is necessary to model the context of real-life situations. Consequently, a mathematical model represents a simplified representation of the phenomenon in question. The process of devising includes the creation of graphs, formulas, equations, inequalities, systems of equations, numerical tables, and algorithms (Swetz and Hartzler, 1991). Given that exponential functions are employed in demonstrations of real-world scenarios and that mathematical models represent simplified representations of phenomena, the teaching of exponential functions necessarily involves the construction of mathematical modelling.

2.7.1. Exponential Function in IB-DP

According to Mathematics: analysis and approaches guide the essential understanding of function, models are depictions of real-life events using expressions, equations, or graphs. A function is defined as a relation or expression involving one or more variables. The creation of different representations of functions, which model the relationships between variables, visually and symbolically as graphs, equations, and tables, represents different ways to communicate mathematical ideas (IBO, 2021). Content-specific conceptual understanding aimed to get the following outcomes for both SL and HL students.

> " Different representations of functions, symbolically and visually as graphs, equations, and tables provide different ways to communicate mathematical relationships.
>
> The parameters in a function or equation correspond to the geometrical features of a graph and can represent physical quantities in spatial dimensions.
>
> Moving between different forms to represent functions allows for deeper understanding and provides different approaches to problem-solving.
>
> Our spatial frame of reference affects the visible part of a function and by changing this "window" can show more or less of the function to best suit our needs.

> Equivalent representations of quadratic functions can reveal different characteristics of the same relationship.
>
> Functions represent mappings that assign to each value of the independent variable (input) one and only one dependent variable (output)" (IBO, 2021, p.35).

Exponential function links to other topics vertically in the IB-DP mathematics curriculum: financial applications of geometric sequences and series. Moreover, exponential function links to other subjects between IB-DP six groups horizontally by using interdisciplinarity.

Exponential function links to other subjects such as biology and chemistry. In the Mathematics: analysis and approaches guide provides suggestions for interdisciplinary connections for exponential function as "radioactive decay, charging and discharging capacitors (physics); first order reactions and activation energy (chemistry); growth curves (biology)" (IBO, 2021, p. 40).

> The phrase "exponential growth" is employed in a variety of contexts to describe a number of phenomena. Is this an erroneous application of a mathematical term? In the context of the theory of knowledge (TOK), the term "exponential growth" is used to describe a number of phenomena. What is the role of models in mathematics? The core part of the exponential function is concerned with the question of whether the role of models in mathematics differs from their role in other areas of knowledge (IBO, 2021, p. 40).

2.8. Williams and Roth's Model of Interdisciplinarity

A conceptualization of "discipline" or "disciplinarity" is necessary to address the issue of interdisciplinary mathematics education. But first, assuming a common, intuitive understanding of discipline, we consider the question of "inter"disciplinarity. Indeed, interdisciplinarity is commonly understood as a complex, partially nested system of concepts in which various types of inquiry are positioned at different levels of the inquiry process' complexity (ICME, 2013).

In this context, "interdisciplinary" mathematics refers to the different ways that mathematics is combined with other fields of knowledge to solve problems and conduct

research. This "other" knowledge is typically not related to mathematics; it could be extra-mathematical or even "everyday" knowledge (like in the case of mathematical modelling of traffic flows, where only a small amount of everyday knowledge is required but the mathematics could be extremely deep), or it could involve one or more other disciplines (like when mathematics is used as a tool within a science, geography, or social sciences project).

When mathematics interacts with other disciplines to become something new and different, a true "inter" disciplinarity arises as the relationship between mathematics and other disciplines grows more interconnected (Williams *et al.*, 2016). There is a process based on usage level knowledge, research, education, and theory between disciplines while looking for answers to any problem.

The interdisciplinary categorizations suggest that transdisciplinary problem-solving can, on reflection, produce meta-disciplinary knowledge that negates disciplinary power (to some extent) and introduces where the second cycle involving the mono-inter-trans-disciplinary knowing becomes a self-aware knowing, in light of the metaknowledge (Williams and Roth, 2019).

The kind of knowledge involved in this cycle certainly includes the understanding of mathematics as "mathematical modelling" for instance. But it also would include an understanding of the particular historical relationship between mathematics and physical sciences or engineering; in the case of the profession of nursing, it might involve the situated appreciation of the relationship between risk and probability, and so on (Williams and Roth, 2019).

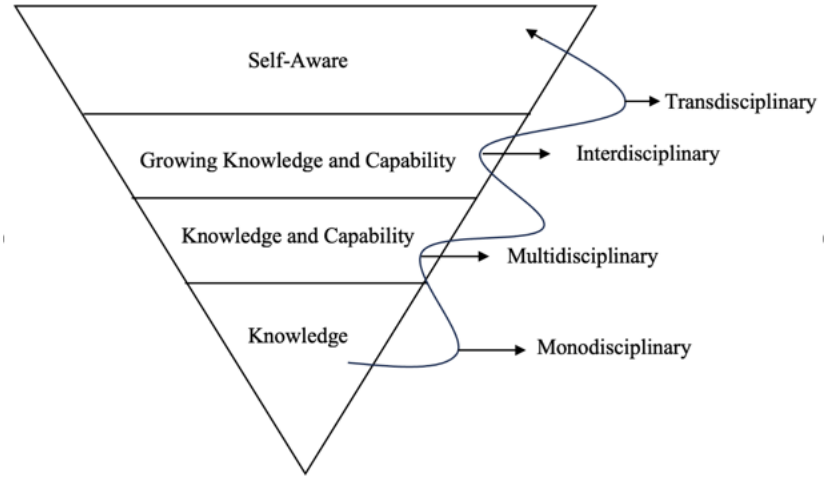


Figure 2.1. A comprehensive meta-cycle of interdisciplinary inquiry.

3. SIGNIFICANCE OF THE STUDY

Enhancing student learning is one of education's primary goals. Students' learning is influenced by a number of factors, including the educational background of their parents, their socioeconomic situation, the curriculum, and teacher-related variables (knowledge, expectations, views). Many aspects of education are described by the factor of curriculum implementation. It is clear that instructor factors interact with curricular implementation as well. (Handal and Herrington, 2003). The curriculum addresses several elements of teaching, including the use of materials and technology, learning objectives, and assessment procedures, and it also offers resources for instruction (Cohen *et al.*, 2003). International Baccalaureate Diploma Program (IB-DP) is one of the most global curricula that has been taught over the world. The IB-DP expands educational opportunities. IB-DP students are not merely interested in their studies. Students are encouraged to develop into self-assured, autonomous learners through the IB-DP. Hence, students gain critical thinking that is encouraged by the IB-DP. After graduation, IB-DP students have a global perspective by gaining an international credential. Students in IB-DP possess time management expertise because during the education process topics are not taught separately. So, IB-DP evaluates more than just academic abilities. The IB collaborates with educational institutions to jointly develop top-notch instruction and further the goal of fostering world peace and betterment. This entails taking down obstacles to lifelong learning and improving support networks that make an investment in students' potential (IBO, 2023). "The IB curriculum document audit revealed that, across programmes, the IB embeds interdisciplinary learning to a high degree. Some of the key areas of strength in IB practice are: scaffolding, pedagogy, problem- and project-based learning, age-appropriateness, development of key skills, and encouraging teacher collaboration and school-wide effort" (Manlove, 2021, p.6). IB-DP is a curriculum implemented in 72 schools in Turkey. In addition to being a global curriculum, interdisciplinary approaches are implemented in the DP. It is important how interdisciplinary studies are integrated and how the six main courses and assessment processes integrate this situation. Since the Mathematics

Analysis and Approaches course, one of these six main courses is given by most schools in Turkey, it is necessary to examine the other interdisciplinary approach of this course and proceed on a specific subject while looking at interdisciplinarity. Since the subject of exponential function is a common subject in more than one discipline, analyzation of how teachers apply the IB-DP curriculum gives information on this subject. Thus, interdisciplinarity implementation in both the instruction and assessment processes of IB-DP provides a unique context to study.

4. STATEMENT OF THE PROBLEM

4.1. Variables

The variables of this study were years of experience as an IB-DP mathematics teacher, lecture teaching level (Standard-Level (SL), High-Level (HL)), school types (state and private), and teachers' conception of interdisciplinarity.

4.2. Research Questions

This study aimed to explore Turkish IB-DP Mathematics teachers' conception of interdisciplinarity usage while teaching their lessons. Therefore, the study investigates the following questions:

(i) How do Turkish IB-DP mathematics teachers incorporate interdisciplinarity into instruction?

   a. How do Turkish IB-DP mathematics teachers incorporate interdisciplinarity into teaching of exponential functions?

(ii) How do Turkish IB-DP mathematics teachers incorporate interdisciplinarity into assessment processes?

5. METHODOLOGY

The purpose of the current study was to explore and understand interdisciplinarity while teaching IB-DP curriculum mathematics topics and the assessment process.

5.1. Research Design

"Qualitative research as an iterative process in which improved understanding to the scientific community is achieved by making new significant distinctions resulting from getting closer to the phenomenon studied" (Aspers and Corte 2019, p.139). According to Yin, case study research entails examining a case (or instances) in the context of a modern, real-world situation. A physical entity, such as an individual, a small group, an organization, or a partnership, may be involved in this instance. Less specifically, it may be a project, a connection, a community, or a decision-making process (2014). In case study research, a real-world, contemporary bounded system (a case) or several bounded systems (cases) are investigated over time by the researcher using a qualitative approach and thorough, multi-source data collection (e.g., observations, interviews, audiovisual material, documents, and reports), which results in the reporting of a case description and case themes. A case study may use a single case (a within-site study) or numerous cases (a multisite study) as its unit of analysis. (Creswell and Poth 2016). In this study, there were eight IB-DP teachers who teach both standard level (SL) and higher level (HL) and work in both private and state schools in Istanbul. The aim of the study was to examine different IB-DP teachers' interdisciplinarity usage while teaching exponential function and assessment processes. Semi-structured interviews were conducted with eight teachers to gain further insight. Subsequently, a second semi-structured interview was conducted with four teachers chosen from these of the eight teachers. Case studies are particularly well suited for naturalistic generalizations based on the empirical transformation of tacit knowledge into explicit knowledge. In any case, case studies are particularly suitable for comprehensive and in-depth descriptions of complex social phenomena. Indeed, the case

study method is renowned for its depth of analysis (Gerring, 2004). Consequently, the four teachers selected from the first group of eight are well-suited for extensive and in-depth descriptions of complex social phenomena, including their conceptions of interdisciplinarity and their teaching approaches to instruction and assessment processes. According to Yin (2009), the selection of cases in a multi-case study should be guided by the objective of either literal replication, whereby each case predicts similar results, or theoretical replication, whereby each case predicts contrasting results but for anticipatable reasons. This study was conducted with the objective of gaining in-depth insight into the practices of four IB-DP mathematics teachers who were chosen from the first eight IB-DP mathematics teachers. This was not done with the intention of differentiating the teachers, but rather to gain an in-depth understanding of how the four IB-DP teachers who demonstrated similar results, or theoretical replication, utilized interdisciplinarity in their instructional and assessment processes. To be able to examine each four teachers' conceptions about interdisciplinarity in their instructions and assessment process deeply each teacher was considered as one case. For this reason, multiple case study was used as a research design for this study.

5.2. Participants

The participant selection was discussed in this section. The participants were IB-DP mathematics teachers from different contexts in Istanbul. Individual semi-structured interviews were conducted with eight teachers for qualitative data collection. The IB-DP mathematics curriculum comprises two programs: Applications and Interpretations (A and I) and Analysis and Approaches (A and A). In Turkey, particularly in Istanbul, the majority of state and private schools utilize the Analysis and Approaches (A and A) program. For this reason, there was at least one for each Analysis and Approaches Standard Level (A and A-SL) for private and state teachers and Analysis and Approaches Higher Level (A and A-HL) for private and state teachers. The IB-DP Mathematics: Analysis and Approaches course acknowledges the requirement for analytical proficiency in a world where a profound grasp of mathematics is becoming more and more necessary for creativity. For A and A-SL teachers there are 150 total

teaching hours for the standard level and A and A-HL 240 hours for the higher level. Moreover, designed for students who are exceptionally more successful in mathematics and/or who want a strong foundation in mathematics for university courses, the A and A-HL course is full of difficult material, including advanced calculus, that will take a lot of time and effort to master. Conversely, the A and A-SL course, although equally demanding, is designed for individuals with average mathematical aptitude and could be better appropriate for those pursuing fields with fewer mathematical prerequisites. Also, there are differences between IB-DP private and state schools in terms of the culture, preparation, resources, and approaches ways to students. Culture represents the school's cultural setting and the application of cultural rules within the school. Teachers' approaches to students in the process of reflecting on the culture and the situation in meeting the students' needs during the IB-DP period also differ between state and private schools in terms of one-on-one meetings and spending time with students.

In order to focus on participating teachers' practices, a mathematics subject needed to be chosen. This way, teachers may provide rich discussion with examples from classroom instruction to show the inclusion of interdisciplinary thinking. Exponential function is one of the common topics for both standard level (SL) and higher level (HL) Analysis and Approaches mathematics of IB-DP. The topic links to other subjects such as biology and chemistry. The Mathematics: analysis and approaches guide provides suggestions for interdisciplinary connections for exponential function as "radioactive decay, charging and discharging capacitors (physics); first-order reactions and activation energy (chemistry); growth curves (biology)" (IBO, 2021, p. 40). This situation is given in the Mathematics: analysis and approaches guide de as links to other subjects. For Theory of Knowledge (TOK), the aim is to find answers for "What role do "models" play in mathematics? Do they play a different role in mathematics compared to their role in other areas of knowledge" (IBO, 2021). The assessment component of the IB-DP includes the Internal Assessment (IA) and the Extended Essay (EE). Internal assessment is an integral part of the course and is compulsory for both SL and HL students. It allows students to demonstrate the application of their skills and knowledge and to pursue their personal interests without the time constraints

and other restrictions associated with written examinations. The internal assessment requirement at SL and HL is an individual inquiry. This is a piece of written work in which students investigate an area of mathematics within other disciplines. (IBO, 2021) On the other hand, an extended essay (EE) in mathematics is intended for students writing on any topic with a mathematical focus and need not be restricted to the theory of mathematics itself (IBO, 2018). For this reason, eight teachers were selected by using purposeful sample selection to conduct this study.

The names of all participants are pseudonymized.

Table 5.1. Demographic information of participants.

Teachers' Pseudonyms	Bachelor's Degree Department	Years of Being Teacher	Years of Being IB-DP Teacher	Type of School	Teaching Level of IB-DP
Arda	Teaching mathematics	23	1	State	HL
Buket	Teaching mathematics	13	4	Private	SL
Ceren	Teaching mathematics	11	7	Private	HL
Ece	Teaching mathematics	22	9	Private	HL
Elif	Teaching mathematics	9	3	Private	HL
Efe	Mathematics	9	4	State (high-achieving)	HL
Eren	Mathematics and Teaching mathematics double major	23	5	State (high-achieving)	HL
Nil	Teaching mathematics	6	3	State	SL

It is worth noting that the number of IB-DP classes in state schools is relatively limited, with one or two classes per school. These classes are designed for students who have demonstrated high levels of academic achievement. As a result, most state schools offer HL mathematics education, while very few schools offer SL. This distribution of classes reflects the fact that the number of mathematics teachers in these schools is relatively small, with one teacher who is highly qualified in the field. This teacher is responsible for carrying out all the work related to the IB-DP.

On the other hand, private schools tend to have larger class sizes than state schools, which can result in more than one SL and HL class being involved in the IB-DP. Students selected for the IB-DP are those who have demonstrated an average or above level of achievement. In order to ensure the highest standards are maintained, more than one mathematics teacher with the appropriate qualifications conducts the programme.

After first phase of semi-structured interviews, the second semi-structured interviews were conducted with the purposeful selection of four teachers who were above the multidisciplinary level. The results of the interviews and the identified themes will be discussed.

5.3. Data Collection

This study aimed to explore IB-DP mathematics teachers' conception of interdisciplinary teaching opinions of these methods within the framework of the IB-DP Curriculum. In light of this aim, semi-structured interview questions (Appendix A and B) were used as instruments.

5.3.1. Semi-Structured Interviews

I conducted semi-structured individual interviews with participants in order to understand teachers' interdisciplinarity teaching views about these practices in the con-

text of the IB-DP Curriculum. Interview questions were prepared based on Williams and Roth, 2019 according to levels of usage of interdisciplinarity. By doing that, I aimed to explore, probe, and ask additional questions during interviews. I prepared the interview questions and pilot testing was done before the first and second semi-structured interviews. It took approximately 30 minutes. During the pilot interview, the ideas about interdisciplinarity and its perspective on the teacher's instruction and assessment processes were covered. After the pilot interview, I reorganized the questions for the first and second semi-structured interviews. By doing that, the first semi-structured interviews included general conceptions about the interdisciplinarity of participants and the second semi-structured interviews were related to specific conceptions of participants about instructional and assessment process of IB-DP.

Eight questions formed the main structure of the first interviews and the researcher added some other questions according to the answers of the participants and the semi-structured interview questions (Appendix A) were asked. In order to gain insight into the perspectives of the eight teachers on the IB-DP curriculum and interdisciplinary thinking, interviews were conducted via Zoom, that were lasted approximately 30 minutes, at a time and place that suited the interviewees. Following the semi-structured interview with eight teachers, all participants who demonstrated a potential for becoming interdisciplinary level were invited to participate in a second interview through a process of purposeful selection.

Seven questions formed the main structure of the second interview and the researcher added some other questions according to the answers of the participants. The semi-structured interview questions (Appendix B) were asked. In order to gain insight into the manner in which the four IB-DP teachers who were invited to participate in the second interview employed interdisciplinary approaches in their pedagogical and evaluative practices, the interviews were conducted over a period of approximately 30 minutes and were conducted via Zoom.

5.3.2. Artifact Analysis

There were two types of artifact analyses which are IB-DP resources and lesson materials. IB-DP resources include books, digital platforms such as Kognity, ManageBac, prepared booklets, IB-DP Standards, etc. Moreover, lesson materials consist of lesson plans, lesson activity sheets, etc. In order to facilitate the analysis of the course materials used, the four teachers were asked to share the materials they had prepared for their lesson plans. Of the four teachers, two were shared their lecture materials. The remaining two were asked instead to describe the content of the materials they use. The objective of this study was to gain insight into how teachers employ interdisciplinary approaches in IB-DP mathematics education. To this end, the artifact documents that are lecture materials were analyzed to examine the extent to which the lecture material aligns with the integration of interdisciplinary and pure mathematical concepts that teachers use during the teaching process.

5.4. Data Analysis

The interviews were recorded and later transcribed in preparation for data analysis. All transcriptions were read in order to understand the data. In general, the act of noticing is the process of taking notes based on observation, recording events or interviews, gathering documents, and so forth. In the analysis phase, when going through the data, it is common to mark important sections and add a descriptive name or code to them. This is the initial step of coding and is referred to as open coding (Khandkar, 2009). Therefore, the open coding process was then applied to each interview. The main questions of the first semi-structured interview were asked to eight teachers and the second semi-structured interview was asked to four teachers. After obtaining their ideas about interdisciplinarity in the teaching and assessment process of IB-DP, the emerged codes were categorized into groups. These categories were analyzed using different coding strategies. There were three themes, curriculum, interdisciplinary thinking, and implementation of interdisciplinarity, which emerged after the first phase of the interview. For the second interview phase, modelling, conceptual

understanding and procedural fluency, the nature of the school, and the requirement of assessment in the IB-DP curriculum emerged as themes. The inductive approach was used. The inductive approach allowed for flexibility in collecting and analyzing data without preconceived categories or theories to guide the data analysis procedure to identify emerging themes, and concepts.

Table 5.2. First level of interviews.

Themes	**Codes**	**Some Examples**
Curriculum	Supportability	The curriculum, from the most basic to the most advanced levels, should support the learner in an interdisciplinary way.
	Improvability	Students' vision is developed through the IB-DP curriculum.
	Suitability	The IB-DP is well-suited to interdisciplinary studies in terms of both its program and its content.
Interdisciplinary Thinking	Multiple perceptiveness	The capacity to consider a multiplicity of perspectives and to interpret from a variety of points of view.
	Relationship with other disciplines	The intersection of mathematics with other disciplines.
	Critical analysis	A critical analysis of a given subject must take into account the interrelatedness of the various aspects that constitute the field of study, both within the subject itself and in relation to other positions, other courses of study, and other concepts within the broader discipline.

Table 5.2 First level of interviews. (cont.)

Themes	**Codes**	**Some Examples**
Implementation of Interdisciplinarity	Knowing other disciplines	I would like to gain a deeper understanding of two or three disciplines related to mathematics, both culturally and in terms of their interdisciplinary relationships.
	Communicating with experts	It is possible to contact individuals engaged in other academic disciplines and engage in discourse and the exchange of ideas with them.
	Appropriateness for mathematical topics	The interdisciplinary application of the appropriate subject matter, its content, and comprehension of the outcome is achieved.

Table 5.3. Second level of interviews.

Themes	**Codes**	**Some Examples**
Modelling	Investigation activity	The investigation activity already includes questioning sentences from a variety of fields. However, beyond that, the questions to comprehend the exponential function initially present a daily life problem, then provide some of the data in the table. Subsequently, the student is asked to find the other data using the method previously described. Consequently, the student gradually progresses from there to the formula.
Conceptual Understanding and Procedural Fluency	Mathematical big idea	We discussed the exponential function through a series of inquiries that provided context for the concept. We proceeded by defining the exponential function and proceeded to discuss its properties.

Table 5.3 Second level of interviews. (cont.)

Themes	**Codes**	**Some Examples**
	Mathematical usage	First, I generated the graphs and proceeded to discuss the concept of an asymptote. For instance, I demonstrated that the exponential function possesses a horizontal asymptote, which is not apparent due to its position within the exponential function. I posed questions to illustrate that the asymptote manifests as the function varies in its translation movements.
Nature of School	School and culture and perspective for IB-DP implementation	In addition, our department head has requested that we include links to TOK resources, guides, or cases, whichever is most appropriate, and that we devote as much time as possible to this in our lessons.
	Teacher's perspective for IB-DP implementation	In the process of preparing the syllabus and lesson plan, I began with this problem, assuming that it would serve as an illustrative example drawn from a realistic context, one that would be readily comprehensible to students.
Requirement of Assessment in IB-DP Curriculum	Assessment process	I introduce IA logic to them and want them to prepare an outline. That outline is very simple since I expect them to get into the subject a little bit, why they chose it, and what kind of mathematics it will be they want to work on it.
		When I say water to students, the things that come to their minds are dams, rain,

Table 5.3 Second level of interviews. (cont.)

Themes	**Codes**	**Some Examples**
		drinking water rate, annual rainfall, or the amount of water in rivers. So, I want them to create a concept map based on such a concept.
	Using different disciplines	One of my students, in his IA study, went through a model by entering the tangents of a door's engraving, etc. This was something in daily life. In other words, it was a work that directly combined architecture and mathematics.

5.5. Role of the Researcher

During the study, I conducted all the semi-structured interviews. I am also a Standard Level (SL) teacher of IB-DP at a private high school in Istanbul. I have some experience and knowledge of the IB-DP curriculum and the role of interdisciplinarity in the IB-DP curriculum which guided me while conducting interviews. I contacted my colleagues IB-DP mathematics teachers employed in various state and private educational institutions to request their participation in my study. As an IB-DP SL teacher, I attempted to conduct the study as though it were a conversation between two educators, striving to maintain the same conversational tone and structure as would be expected in such an interaction. I was sharing my powers with participants and to measure their ideas. I was careful not to ask leading or judgmental questions or make judgmental remarks throughout the interviews. Particularly during individual interviews, I avoided making any facial expressions that would be perceived as unfavorable. During the interviews, I was able to ask follow-up questions as needed thanks to the semi-structured individual interviews. Since the study aimed to examine IB-DP Mathematics teachers' conception of interdisciplinarity and their teaching approach, I tried not to disturb the natural settings of semi-structured first and second phases of interviews.

5.6. Validity, Reliability, and Trustworthiness

When validity and reliability are taken into account, a study's quality rises. Nevertheless, the data in qualitative investigations prevent researchers from performing numerical analyses of dependability and validity. Trustworthiness was employed by Lincoln and Guba (1985) as a metric for assessing the validity and reliability of qualitative research. The significance of a qualitative study's findings is explained by trustworthiness (Merriam, 2009).

Triangulation is defined as using different kinds of methods or sources of data in qualitative research to develop a comprehensive understanding (Patton, 1999). One way to validate findings in qualitative research is through triangulation. According to Lincoln and Guba (1985), there are four requirements to raise trustworthiness which can be listed as (i) credibility; (ii) transferability; (iii) dependability; and (iv) conformability.

Credibility is defined as a measure of the accuracy and correctness of the findings of a study. To be able to ensure credibility, I looked at IB-DP Standards, books, online education platforms such as Kognity, etc. Guba (1985) suggested triangulating and looking at different types of data to help build credibility.

Transferability is defined as a measure of whether study findings apply to other contexts, circumstances, and settings. Interviews were done by the researcher to get the qualitative data. To reduce the chance of missing data, I meticulously recorded and subsequently transcribed the interviews. The participants' actual words were captured in the transcriptions. To improve transferability, each analysis was given as much information as feasible utilizing quotes from the interviewees.

To improve reliability and validity, qualitative data was gathered and analyzed for this study. Peer review was also carried out for validity by exchanging thoughts at each level of the study with the researcher's adviser.

To enhance interrelated reliability, the member check method was employed. Consequently, each participant was contacted individually and asked whether the information they shared was comprehended correctly and whether they had any additional ideas to contribute. The interrelated method was satisfied by the member check method, which was used to verify the results.

5.7. Ethical Considerations

Ethical approval and written permission were obtained from the Science and Engineering Ethics Committee of Bogazici University with the number of 2023/30 (Appendix C). The researcher introduced herself to the IB-DP teachers and then explained the aim of the study, the data collection procedure, and what was expected from them. Informed consent Informed consent (Appendix D) was obtained from all participants to use their data from the semi-structured interviews.

6. FINDINGS

In this section, the findings of the current study presented in two parts; i) qualitative data for eight IB-DP teachers who are teaching both standard level (SL) and higher level (HL) Analysis and Approaches mathematics of IB-DP at different types of state and private schools. ii) qualitative data for four IB-DP teachers who were chosen from eight teachers based on their instruction and assessment conceptions about interdisciplinarity while teaching IB-DP standard level (SL) and higher level (HL) Analysis and Approaches (A and A) mathematics.

The eight teachers have general conceptions about interdisciplinarity and IB-DP were explored through semi-structured interviews. The interviews revealed that the teachers differed in their conceptions about curriculum, interdisciplinary thinking, and implementation of interdisciplinary practices. One teacher's approach to instruction is monodisciplinary, the approach of three teachers is multidisciplinary, and the four teachers' approach could be categorized as transitioning between multidisciplinary and interdisciplinary practices.

These four teachers whose approach was considered as between multidisciplinary level and interdisciplinary level were selected to conduct the second interview. They were well-suited for extensive and in-depth descriptions of complex social phenomena, including their conceptions of interdisciplinarity and their teaching approaches to instruction and assessment processes. The second semi-structured interview provided insight into the teachers' modelling, conceptual understanding, procedural fluency, and the nature of school and requirements of the IB-DP curriculum.

6.1. Turkish Mathematics IB-DP Teachers' General Conceptions About IB-DP

According to eight participants' views of Turkish Mathematics IB-DP Teachers' general conceptions about IB-DP from the first level of the semi-structured interview's themes which were *curriculum, interdisciplinary thinking, and implementation of interdisciplinary* were observed. Based on the themes the findings from the interviews were analyzed according to Williams and Roth (2019). According to Williams and Roth (2019), there is an ongoing process that starts from the beginning level of monodisciplinarity to the highest level of transdisciplinary. The aim of the disciplines is to find an appropriate solution for undisciplined problems. The process begins with trying to find suitable knowledge which occurs at the level of monodisciplinarity. Then, if modelling is added to knowledge while the process continues the second level which is multidisciplinarity emerges. While ongoing processes of knowledge and modelling capability of more than one discipline are added. Then this new process starts to grow in terms of integration of more than one discipline to solve the given undisciplined problem that is called interdisciplinarity. During the process, if self-awareness is seen at the level of interdisciplinarity then the process reaches its final level which is called transdisciplinarity.

6.1.1. Curriculum

The first theme was curriculum which has the points that the participants focused on the most are the nature of IB-DP curriculum and other Curricula which are Ministry of National Education (MoNE), and Advanced Placement (AP) Curricula taught in Turkey. The nature of IB-DP includes the requirements and implementation areas. The former includes the development of a learner profile, teaching and connecting within and between disciplines, and application of curriculum whereas the latter includes a learner profile, nature of mathematics, other curriculum perspectives, and flexibility of teachers for implementations.

Arda says "*A good and grounded curriculum*" and "*This is important whether the teacher can fully fulfill the requirements of this curriculum.*" However, Arda adds "*But since I am new, I have the mentality of teaching topics and solving questions, so I am missing out.*" This shows that Arda is at the level of monodisciplinarity so, he has just knowledge about disciplines. This may be expected due to having some limited time and adaptation of IB-DP while Arda is an expert on the Ministry of National Education (MoNE) curriculum.

For Elif, the IB-DP curriculum is "*The curriculum offers teachers a method and the curriculum also guides students*". Elif knows some properties of IB-DP and adds "*We have common topics, common intersection topics, the program is suitable in terms of content, but it is passed quickly.*" which shows Elif's level is exactly multidisciplinary. Even though Elif has four years of experience in IB-DP she cannot gain insight into being interdisciplinary.

Moreover, four teachers out of eight teachers are neither at the level of multidisciplinary nor interdisciplinary they can be considered as being between multidisciplinary and interdisciplinary levels which was needed to give a new name for this level. For this study, I labeled this in-between state as becoming interdisciplinarity level. These teachers are Buket, Ceren, Eren, and Nil with an average of five years of experience for teaching IB-DP curriculum SL and HL A and A mathematics.

For example, Nil says "*If teaching with simultaneous disciplines is ensured, a jointly developing thought system is formed. The curriculum can be supportive in this regard.*" Since she has an idea that IB-DP gives them room for the application of interdisciplinary working areas which shows that Nil is at the level of becoming interdisciplinary level.

6.1.2. Interdisciplinary Thinking

The second theme was interdisciplinary thinking which has teachers' ideas about the nature of mathematics, the relationship between mathematics and other disciplines, pure mathematics and interdisciplinary mathematics topics, and their perspectives on teaching IB-DP mathematics.

Buket has ideas about interdisciplinary thinking "*If teaching with simultaneous disciplines is ensured, a jointly developing thought system is formed and while solving a problem, IB also supports interdisciplinary teaching*". Buket is at the level of becoming interdisciplinary level since she has insight into there is integration between mathematics and other disciplines which is supported by the IB-DP curriculum.

On the other hand, Ece has the idea that "*There are some overlaps between physics and mathematics*" for interdisciplinary thinking which shows Ece's level is exactly multidisciplinary because she just says because of overlapping other disciplines are just tools for mathematics.

Efe has an opinion about interdisciplinary thinking "*Interdisciplinary thinking, making joint decisions with other disciplines, being able to act together with them*" which shows Efe at the level is somewhere in the process which means that becoming interdisciplinary level since he just has an opinion about shared areas between mathematics and other disciplines nothing more.

According to Ceren "*I think of the concepts as thinking not in isolation, but in relation to each other, both within themselves and in relation to other positions, other courses, and other concepts*". is related to thinking as interdisciplinarity which shows Ceren is at the level of becoming interdisciplinary level. She has insight into integration and relation between disciplines which is more than just using other disciplines as a tool.

6.1.3. Implementation of Interdisciplinary

The last theme was the implementation of interdisciplinarity in their instructions and assessment procedures which include external assessment, internal assessment (IA) and extended essay (EE). All teachers have their own strategies for different approaches and views on instruction and assessment procedures. For this reason, each teacher examined separately for these two situations. According to Williams and Roth (2019), Arda's approach is at the level of monodisciplinary; approaches of Ece, Elif, and Efe are at the multidisciplinary level; while Buket, Ceren, Eren, and Nil at the level of becoming interdisciplinary level which means they are in the ongoing process.

6.1.3.1. Arda's Instruction and Assessment. Even though Arda has the idea that "*As a teacher, I must have prior knowledge of which discipline it falls into*". This shows Arda does not have any more knowledge about interdisciplinarity between more than one discipline. He just gives interdisciplinary examples by taking benefits from the student's knowledge of physics and biology courses. He does not include interdisciplinarity in his lectures and teaching process. Moreover, he is a 1-year IB-DP teacher so, he does not have assessment experience for implementing interdisciplinarity in either IA or EE. For the reason that he has knowledge about discipline, the level of Arda is the monodisciplinary level based on Williams and Roth (2019).

6.1.3.2. Ece's Instruction and Assessment. Ece has the idea "*I mean, it only happens in physics and physics problems, and when I get stuck on physics problems, I talk to physics teachers*". She takes aid from other discipline experts which shows her intention to usage of interdisciplinarity. Also, Ece adds her approach is more about mathematics rather than other disciplines however using other disciplines while teaching gives benefits to her by making topics more real content-based which enables students to understand easily. She highlights mathematics even though there are some attempts to use other disciplines for this reason, the level of Ece is the multidisciplinary level based on Williams and Roth (2019).

6.1.3.3. Elif's Instruction and Assessment. Elif has opinions about "*If there was enough time, I would use teaching approach physics and chemistry lesson but it remains in theoretically*" She just uses other disciplines as a tool to create a connection between mathematics and other disciplines by underlying the importance of mathematics in different disciplines. She uses other disciplines as a tool to make more mathematics. For this reason, the level of Elif is the multidisciplinary level based on Williams and Roth (2019).

6.1.3.4. Efe's Instruction and Assessment. Efe has opinions about "*Except for IA, I do not use interdisciplinary status in the lecture process*". This shows he only uses different disciplines and their integrations during the information process of the assessment procedure in terms of the internal assessment part. On the other hand, he has a method of teaching that does not include interdisciplinarity even though he knows some particular topics are related to other disciplines explicitly, he prefers to teach mathematics as pure mathematics in his classes. For this reason, the level of Efe is the multidisciplinary level based on Williams and Roth (2019).

There are four teachers out of eight teachers who are at the becoming interdisciplinary level.

6.1.3.5. Buket's Instruction and Assessment. Buket has opinions about "*Begin the lesson by analyzing various questions or situations in connection with other disciplines with the investigation activity*". In terms of the content of the questions, this investigation activity is related to daily life examples such as modelling. Buket tries to construct the topic by taking the help of interdisciplinarity. For this reason, the level of Buket is at the level of becoming interdisciplinary level.

6.1.3.6. Ceren's Instruction and Assessment. Ceren has opinions about "*There should be events that will focus on the intersection of the subject I have chosen with other disciplines, subjects, and concepts. Activity and questions should be structured very*

well into the activity in order to both capture the concept and capture the connection of the concept with other disciplines".She mentions that there should be activities that emphasize interdisciplinarity connections to be able to construct mathematical topics conceptually. She adopted conceptual-based learning as her teaching approach and while doing this, she aimed to apply interdisciplinary work as much as possible in the activities and introduction part, during lesson, and conclusion section of the course. For this reason, the level of Ceren is at the level of becoming interdisciplinary level.

6.1.3.7. Eren's Instruction and Assessment. Eren has opinions about "*I would like them to establish the connection between concepts well. Even if mathematics ends when you reach the number, it is necessary to emphasize physics by paying attention to its units*" He has insight into interdisciplinarity as making connections between disciplines that have common topics. He looks at mathematics not only just for making some calculations of pure mathematics but also for connecting it with other disciplines to create an atmosphere between them. For this reason, the level of Eren is at the level of becoming interdisciplinary level.

6.1.3.8. Nil's Instruction and Assessment. Nil has opinions about "*It means meeting with experts from different disciplines and understanding how they approach the subject. The main subject should be mathematics, but I would like to design a course that requires other disciplines as well, in a way that does not stray too much from mathematics*". She asks different questions that require interdisciplinary knowledge from other disciplines such as geography, physics, chemistry, biology, economics, and psychology to create real-life situations to help students concretize and make understandable the given topics. For this reason, the level of Nil's is at the level of becoming interdisciplinary level.

6.2. IB-DP Mathematics Teachers' Interdisciplinarity Conceptions for Instruction and Assessment

The first semi-structured interview evaluated the interdisciplinarity perspective of eight teachers teaching in private and state schools which are implementing the IB-DP curriculum and how they applied this perspective in instruction and assessment situations. The findings were evaluated according to Williams and Roth (2019), and it was seen that four out of eight teachers' instructional approaches were in the ongoing process which means they are between multidisciplinarity and interdisciplinarity levels which is named as becoming interdisciplinarity level for this study. For this reason, a second semi-structural interview was conducted to understand how these four teachers incorporated their interdisciplinary insight into instruction and assessment. For the instructional dimension, the subject of exponential function, which is a common mathematics topic in both standard-level (SL) and higher-level (HL) curricula. Moreover, the exponential function is a suitable topic for implementation interdisciplinary, as its relationship with other disciplines is clearly stated in the Mathematics: analysis and approaches guide (2019), which was chosen. Participants were asked questions about how they teach this topic and the instructional materials they used while teaching. For the assessment dimension, questions were asked about how they carry out the internal assessment (IA) and extended essay (EE) processes and the relationship between assessment components and interdisciplinarity. As a result of the second semi-structured interview with the four teachers; the instruction dimension focused on the themes of *(i) modelling, (ii) conceptual understanding and procedural fluency, and (iii) the nature of school*; and the assessment dimension focused on the *(iv) requirements of the IB-DP curriculum* dimension.

6.2.1. Instruction

The first component was instruction about exponential function which is a common topic for both SL and HL IB-DP A and A mathematics. Exponential functions are used to model rates of increase or decrease that are proportional to the value of

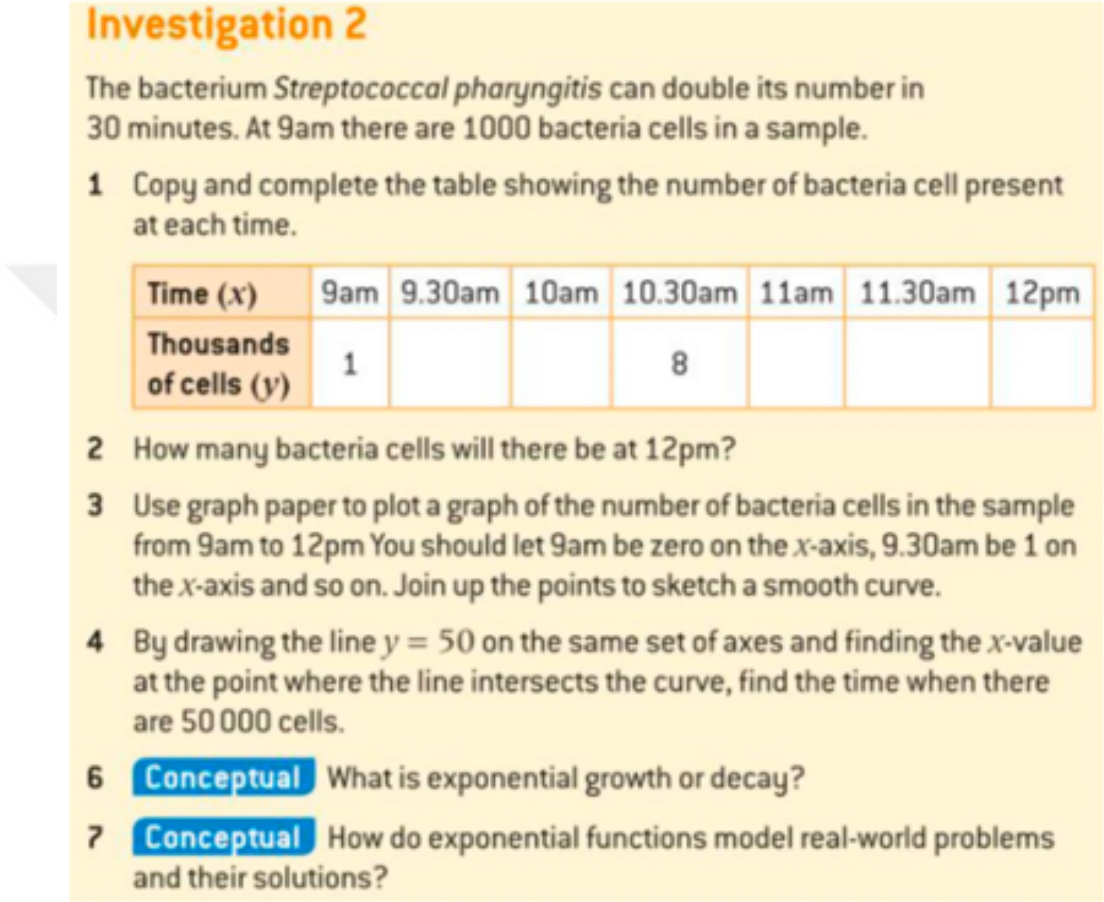
the function. The primary objective of teachers is to facilitate students' capacity to construct this modelling through the lens of the overarching concept of function while lightening up this subject matter. Consequently, the pedagogical approach employed by teachers at the outset of the topic is a pivotal determinant. Moreover, teachers who aspire to integrate this activity into other disciplines through the use of daily-life examples have subtle variations in their instructional techniques based on the modelling, conceptual understanding, procedural fluency, and nature of the schools. Hence, there are slight differences between teachers who are at the level of multidisciplinarity and teachers who are in the becoming interdisciplinarity level. The reason for this small difference is the usage of the IB-DP curriculum in terms of teaching the topic of exponential function.

6.2.1.1. Modelling. All four teachers generally use an investigation activity to start the topic of exponential function. Most of the investigation activity is related to other disciplines for example according to Nil "*I started the lesson with an investigation activity about bacterial population growth whose expressions increase exponentially*". She mentioned there is a connection between mathematics and biology. At the end of the investigation activity, students can learn exponential function by combining their knowledge from biology courses and gain conceptual learning from more than one discipline's perspectives. For Ceren "*In a real-life problem or other disciplines, I try to explain that concepts or the ideas we want to explain through that are given in the investigation activity by conducting a model*". She emphasizes real-life examples that are given through investigation activity are examples of contextual problems. This creates an environment where students can learn knowledge of exponential function with the help of daily life contexts. "*While trying to explain the subject of the exponential function, we used contextual problems which are involved in other disciplines particularly*" is Ceren teacher's opinion about teaching the exponential function by using other disciplines with the aid of a contextual-based learning method. Moreover, there are attempts to ask different kinds of questions that aim to teach the concept of exponential function with inquiry questions by utilizing the investigation activity. Using investigation activity to start exponential function by using investigation activity and

its modelling of real-life contextual problems enables them to focus on mathematics so, the focus is not on the interdisciplinarity between disciplines. Therefore, the use of investigation activities is used to teach exponential function and aim to develop students who are inquirers, knowledgeable, and thinkers as being IB-DP learners.

6.2.1.2. Conceptual Understanding and Procedural Fluency. Exponential function is a function type that consists of properties of both exponential numbers and function properties. Therefore, all four teachers start their exponential function topic by reminding prior knowledge which is related to function properties and exponential number properties. For Eren's teacher's perspective to start the exponential function topic is "*First of all, since they know exponents in the ninth grade as basic knowledge, I will first talk a little about the parts related to exponents.*". He aims to activate students' reasoning as IB-DP learners by trying to construct the topic by taking it at the bottom and building things on top of it to be able to see the big picture. Also, Eren says "*Then since we have already covered function topics, we start arranging it so that it is a one-to-one overlap*". He has a view of structuring his exponential function lesson by cumulating new topics on top of previous ones. After making the connection with prior knowledge, teachers start to follow the investigation activity to reach the definition of the exponential function. While conducting the investigation activity step by step, Buket teacher takes the help of the graphical representation type to represent an exponential function. She says, "*The investigation activity guides students to the exponential function, so they can interpret the exponential function graph*". She aims to activate students' representation as being IB-DP learners by showing different types of mathematical representations. Moreover, students can make connections between topics while learning the exponential function. Eren teacher's students say "*They did not have any difficulties with the problems of exponential functions, because they said that since we processed a geometric series which is similar to the exponential function*". This shows students can go over the mathematics curriculum horizontally. They can look at the similarities between topics by making reasoning that enables them to construct a good understanding of the big picture of mathematical topics. Nil teacher has a perspective of "*I talk about the fact that the increase is an exponential increase,*

that we need to write the function as an exponential expression, and then I tell about the concepts of exponential growth and decay". Figure 6.1 and Figure 6.2 depict some instructional material from Nil teacher.



Investigation 2

The bacterium *Streptococcal pharyngitis* can double its number in 30 minutes. At 9am there are 1000 bacteria cells in a sample.

1 Copy and complete the table showing the number of bacteria cell present at each time.

Time (x)	9am	9.30am	10am	10.30am	11am	11.30am	12pm
Thousands of cells (y)	1			8			

2 How many bacteria cells will there be at 12pm?

3 Use graph paper to plot a graph of the number of bacteria cells in the sample from 9am to 12pm You should let 9am be zero on the x-axis, 9.30am be 1 on the x-axis and so on. Join up the points to sketch a smooth curve.

4 By drawing the line $y = 50$ on the same set of axes and finding the x-value at the point where the line intersects the curve, find the time when there are 50 000 cells.

6 **Conceptual** What is exponential growth or decay?

7 **Conceptual** How do exponential functions model real-world problems and their solutions?

Figure 6.1. Lecture material of Nil teacher.

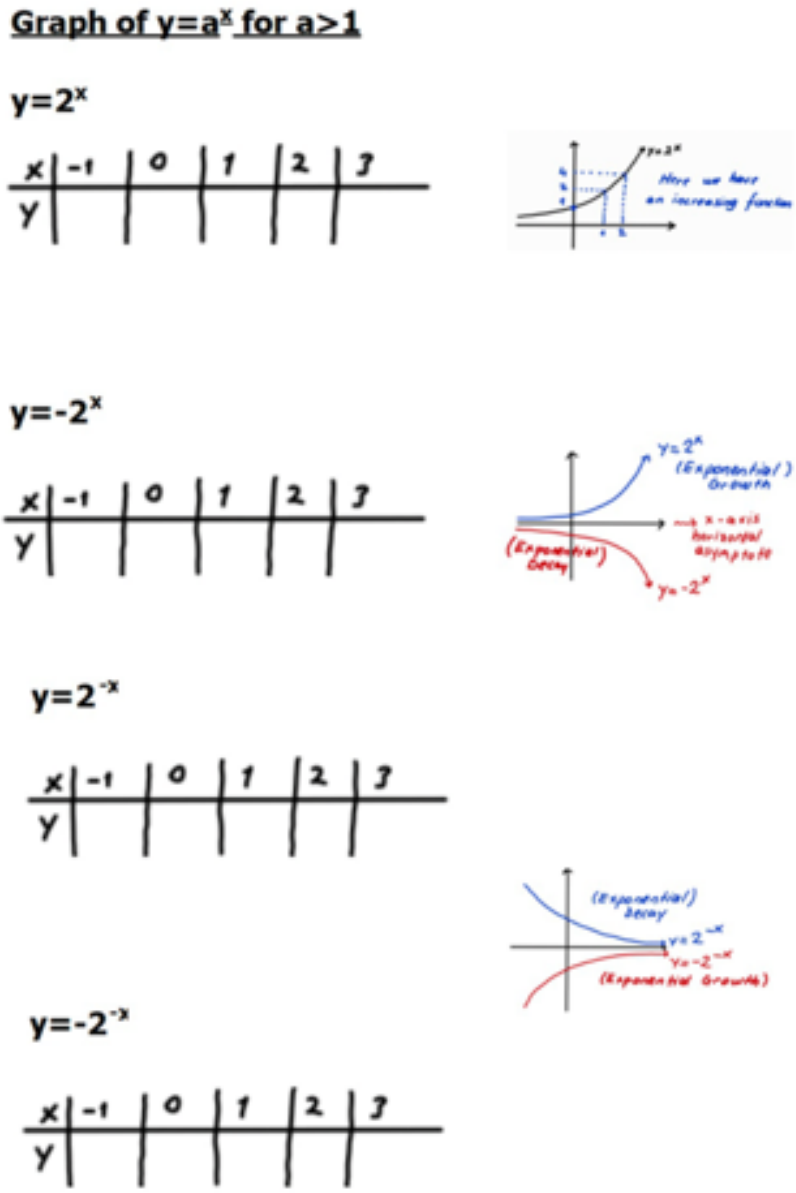


Figure 6.2. Lecture material of Nil teacher.

Here, she focuses on the exponential function's graphical properties by starting from an investigation activity that focuses on the increment of the number of bacteria during a time interval exponentially. She tries to make a connection between pure mathematics by defining and giving properties and reaching a mathematical model of the given contextual problem. Eren teacher also adds, "*There is actually a horizontal asymptote for the exponential function, but it is not visible because it is on the x-axis*". Figure 6.3 and Figure 6.4 show two examples from Eren teacher's instructional material.

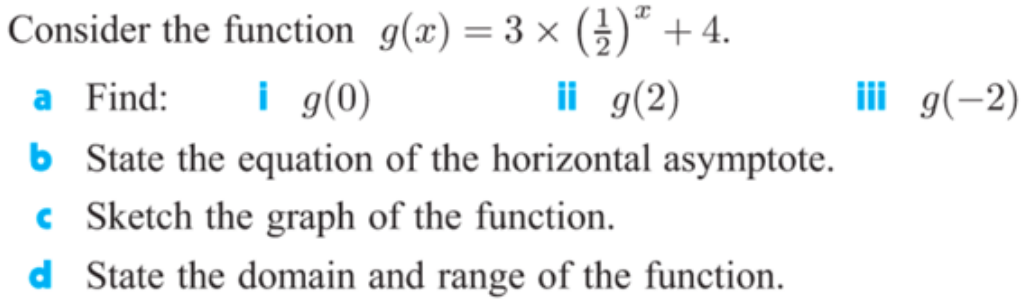


Figure 6.3. Lecture material of Eren teacher.

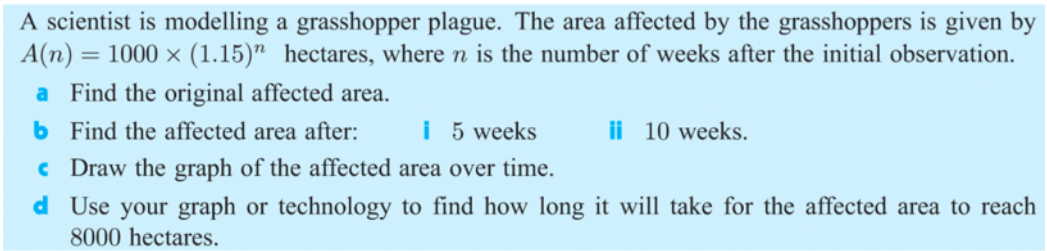


Figure 6.4. Lecture material of Eren teacher.

Both Nil and Eren teachers try also to teach the exponential function by giving its properties as pure mathematics without involving other disciplines. For consideration of the teachers' methods of teaching exponential function, they give priority to conceptual understanding and procedural fluency. For this reason, mathematical modelling is not a tool for them to teach exponential functions. The aim of teachers here is to develop a mathematical teaching method by making use of other disciplines rather than teaching only pure mathematics. They do this thanks to the investigation activity and contextual problems involving some daily life situations that are seen in other disciplines. As a result, it can be said that teacher Eren is trying to do more pure mathematics, he is trying to teach the exponential function through examples from other disciplines. His first focus is more on pure mathematics since he gives importance to the definition and properties of exponential functions. On the other hand, it is obvious that teachers Buket, Ceren, and Nil try to use interdisciplinarity with investigation activity and make contextual-based learning using real-life context. They

use IB-DP books' investigation activities and inquiry-based learning to open up the exponential function. In the end, they also aim to get pure mathematics by giving definitions and properties of the exponential function.

6.2.1.3. Nature and Culture of School. The nature and culture of schools are different from school to school since schools' approaches, schools' cultures and perspectives, school types, and teachers' perspectives are different from each other. According to Buket teacher "*Therefore, we normally have unit plans that we prepare for IB-DP. Beyond that, of course, we also plan on a topic-by-topic basis*". She mentioned everything as we language which means that they prepare everything such as unit plan, lesson plan, and lecture materials, etc. as a team. Her school is a school that embraces progress through teamwork toward IB-DP as a school approach and culture. For this reason, teachers have adopted working as a team from teachers' perspectives. They proceed with a common decision in every decision taken for IB-DP. She also adds "*Since our school is an IB school, all grade levels are not independent units from each other. For this reason, lessons are planned at each grade level, taking into account that the student will be a graduate of a DP school*". This shows that the school as a whole implements the IB-DP philosophy at every grade level and educates all its students with this philosophy and culture. "*Our level leader and department head want us to include the TOK links and the questions in the guide in the course. They want us to spend as much time for this in class as possible*". this is the view of Ceren teacher. As she mentioned there is teamwork which is managed by a team leader and head of department. The school culture and approach for IB-DP implementation is similar to the Buket teacher's school of nature.

From Eren teacher's perspective is that "*I have my own worksheet about the exponential function that I compiled from books*". He makes every step of IB-DP by himself. So, here there is individual work instead of teamwork. Moreover, Nil teacher adds "*I prepared the course material inspired by various books and sources*". Like teacher Eren, teacher Nil teacher prepares course materials individually as well. From here, it can be said that the school culture and approach for IB-DP implementation is

similar to the Eren teacher's school of nature. Both of them need to do everything as an individual being so there is no attempt from school culture and approach.

Only high-performing students from state high schools are selected for the IB Diploma Program in Turkey. As a result, there are only one or two of IB Diploma Program classes available in state schools. At these institutions, all matters pertaining to the IB Diploma Program's mathematical curriculum are handled by a single teacher. In Turkey, students who have demonstrated moderate academic success in private schools are selected for the IB-DP. Consequently, private schools offer a greater number of IB-DP classes than state schools. Given the prevalence of these classes, the number of IB-DP mathematics teachers in a given school is also greater than in state schools. Consequently, in private schools, the teaching of IB-DP mathematics is the responsibility of a team of teachers within the school. Therefore, for four teachers are divided into two different types of schools that are adapted to IB-DP and implemented in different directions. While Nil and Eren instructors make decisions on their own with higher achieved students, Burcu and Ceren teachers consider the IB-DP implementation school strategy and culture as a collective effort with moderate achieved students.

6.2.2. Assessment

The assessment component of IB-DP includes external assessment, internal assessment (IA) and extended essay (EE). External assessment constitutes the primary means of assessment for the majority of courses. This is due to its high levels of objectivity and reliability. The external assessment encompasses a range of question types, including essays, structured problems, short-response questions, data-response questions, text-response questions, case-study questions, and multiple-choice questions, which are incorporated into the examination papers. IB-DP students are required to complete the Internal Assessment (IA) in order to evaluate their current standing in regard to the goals outlined in the IB-DP. So, it helps to see the students' subject-specific knowledge, skills, etc. There are several components to this assessment criterion that

need to be assessed. The following are the performance levels or categories: research, data analysis, conclusion and assessment, presentation, and personal engagement of motivation. The extended essay (EE) is an independent research project, culminating in a 4000-word paper. It provides students with the opportunity to develop their research skills and to investigate a topic of personal interest, which must relate to one of the six DP subjects or take the interdisciplinary approach of a World Studies extended essay.

6.2.2.1. Requirements of the IB-DP curriculum. Given the necessity of a distinct preparation process for each type of assessment, it is imperative that teachers ensure that the process they implement is the most effective for their students. In light of this, every IB-DP teacher guides his or her students through external assessment, IA, and EE, and helps them to prepare in the most optimal manner. In this perspective, all four teachers explained the process by paying attention to what IA is, what are its criteria, what is expected from them, what is the purpose of IB-DP in this assignment, and why there is such an assignment. By doing that both Nil and Eren teachers give students an idea of creating a concept map based on theme of water which is given IB-DP sources explicitly. Nil teacher adds "*When I say water to students, the things that come to their minds are dams, rain, drinking water rate, annual rainfall, or the amount of water in rivers. So, I want them to create a concept map based on such a concept*". By doing that she gives the idea of IA basically by using the theme of water.

Unlike Eren and Nil teachers, Buket and Ceren teachers did not mention such a conceptual mapping by using IB-DP sources which are school resources and experience that comes from the number of students. Ceren says "*I introduce IA logic to them and want them to prepare an outline. That outline is very simple since I expect them to get into the subject a little bit, why they chose it, and what kind of mathematics it will be they want to work on it*". The way they follow for IA process is by giving information about IA and its procedure and then moving on to the first step without creating any conceptual mind map. While teachers' expectations in the IA process are the same, their styles in this process are different. After starting the process of IA, all four

teachers mentioned about flexibility of topic selection of students for their IA's. Ceren teacher has a comment on this "*In fact, of course, we leave the students free. They can study any subject they want for IA*". It is important to give freedom to students what they want to work on based on their interests. According to Nil teacher, "*I think IA is actually a very suitable assignment for interdisciplinary work in this exploration. Because when they combine something that is their field of interest with mathematics, for example, their field of interest may be art, they establish the relationship between art and mathematics*". Therefore, in the IA process, teachers' starting point is not doing pure mathematics, but rather they shift towards different disciplines. For instance, Eren teacher says "*One of my students, in his IA study, went through a model by entering the tangents of a door's engraving, etc. This was something in daily life. In other words, it was a work that directly combined architecture and mathematics*". So, examples of IA include mathematics and other discipline integration which enables students to work on interdisciplinarity. While processing the IA process, all four teachers feel more flexible to be able to connect mathematics with other disciplines such as chemistry, physics, statistics, arts, architecture, etc.

The extended essay is an independent, self-contained research project that every IB-DP student must do. For the procedure of EE, all teachers who have experience, firstly describe what EE is. Then they set of outline for steps that need to be taken by students. Again there is flexibility for choosing topic selection for students. "*During the EE process, students make their own subject choices*". said Buket teacher. This is similar to the IA process. So, for the assessment part of IB-DP in terms of projects students are free to choose topics that they want to work on. In contrast to IA, there is a little bit of interference of interdisciplinary work for EE. Eren teacher says "*To be honest, though, students did not do much in the interdisciplinarity because their focus was primarily mathematics*". Ceren teacher has the same situation that is "*Last year, two of my students studied pure mathematics. There were proofs in the project. Actually, there was no point for him to switch to another discipline*".

While IA offers students the relationship between combining mathematics and other disciplines with examples from daily life, on the contrary, for EE it has become a type of project where mathematics is more at the forefront and pure mathematics is done. According to all four teachers, IA is more likely to work with interdisciplinarity, therefore they are closer to the interdisciplinarity level in the ongoing process. The reason for this is that the IB-DP assessment criteria provide them more opportunities for interdisciplinary work and they feel more comfortable at this point. For the EE part, students who are interested in pure mathematics choose to topic to show their interest and teachers just guide them on their journeys.

7. DISCUSSION

7.1. Influence of Curriculum

The IB-DP is a two-year international education program designed for students between the ages of 16 and 19. The program's objective is to prepare students for the transition to university life. Its mission is to cultivate inquiring, knowledgeable, and caring young people who will contribute to a more peaceful and prosperous world through intercultural understanding and respect. Therefore, the IB-DP curriculum aims to be a globally applicable curriculum that is oriented towards developing globally minded individuals, which is reflected both in its vision and its mission (IBO, 2023). The programme has been implemented towards in this direction for a number of years. In Turkey, the IB-DP curriculum is taught in both state and private schools, with the majority of these institutions located in Istanbul. The objective of this study is to gain insight from the opinions of teachers rather than attempting to generalize.

7.1.1. Intended and Enacted Curriculum

In Istanbul, Turkey, the IB-DP curriculum is implemented exclusively with high-achieving students in state high schools, whereas the private schools usually serve to students from mixed ability groups. These state schools accept students through the national high school entrance exam. The student profile of these schools is usually in the top one percent. Some of the participating teachers in this study were working at schools which accept the top 0.1 percent of students. This very high-achieving school culture influences how the curricula are implemented. On the other hand, only a limited number of private high schools accept students with the national exam. For the majority of the private schools in Istanbul with IB-DP programs, the schools are considered to serve mixed-ability students. However, the school administrations prefer to implement IB-DP with above-average students. These student profile conditions, having very high achieving on the one hand and mixed ability on the other hand may

influence how teachers at these schools implement IB-DP programs. This discrepancy affects the implementation of the IB-DP curriculum. It is only natural to accept some differences between the intended and enacted curriculum for these schools.

In literature, the alignment between curriculum standards, instruction, and assessment facilitates communication about the content students are expected to learn and the content teachers are required to teach. This alignment represents a necessary condition for assessment results to yield valid inferences about what students know (Kurz *et al.*, 2010). The process of determining the alignment between curriculum, instruction, and assessment typically begins with the identification of the content of each element (Porter, 2002). The initial challenge is the translation of all information into a unified language framework that enables subsequent comparisons and judgments of agreement between the various contents. In order to facilitate alignment, Porter (2002) distinguished between the content of three distinct types of curricula: the intended, enacted, and assessed curricula. The intended curriculum is defined by the content standards for a specific subject and grade level. The content of instruction delivered by classroom teachers constitutes the enacted curriculum, while the content measured by student assessments represents the assessed curriculum. While national curricula may now provide clear guidance to schools and teachers, the transition from policy documents to enacted curricula is not necessarily a rational and linear process. It is more realistic to view national curriculum policy as the initial step in the process of interpretation that ultimately influences what students experience and learn in the classroom. These influences originate from sources within the educational context that support and promote particular interpretations of worthwhile learning. These sources of influence are contexts or arenas of action where participants have shared understandings of concepts and ideas due to the shared social contexts such as national curriculum policy statements, professional development for teachers, teachers' beliefs and values about teaching and learning, etc. (Hume and Coll, 2010).

In this study, the findings showed that the difference between the intended and the enacted curriculum was due to teachers' simultaneous implementation of more

than one curriculum which are The Turkish Ministry of National Education (MoNE) and International Baccalaureate Diploma Program (IB-DP). The Turkish Ministry of National Education (MoNE) offers a four-year program for students between the ages of 14 and 18. The program's mission is to educate students according to their interests, desires, and skills, while also contributing to the production of qualified human resources as a driving force of community development (MoNE, 2021). The curriculum of the MoNE consists of 14–15 common subjects and one or two elective subjects for students in the 9th and 10th grades. In the final two years of high school, students are required to take eight or nine core subjects and approximately ten elective courses based on their individual interests (MONE, 2023). Student work is evaluated on an ongoing basis at each grade level. Upon completion of the twelfth grade, students are required to take the national university entrance examination. The grade achieved on this examination has a significant impact on university placement, particularly in comparison to the high school grade point average (GPA). Consequently, the format and questions of the examination have an impact on the teaching methods and applied curricula.

In this study, the reason for the differences between the two curriculum types was attributed to cultural differences. The teachers who participated in the study were trained using the MoNE curriculum and subsequently became MoNE teachers. As they are engaged in both training and teaching, the MoNE curriculum exerts a dominant influence. These teachers, who are well-positioned within the MoNE curriculum, be able to transition to become IB-DP teachers due to their competencies. MoNE employs an assessment-based curriculum, which is reflected in the IB-DP schools' preparation of their students for the IB-DP in the ninth and tenth grades. As a result of this situation, they continue to work as both MoNE and IB-DP teachers. This is because IB-DP teachers also teach in the MoNE curriculum, which means they are not disconnected from different curriculum types. Consequently, IB-DP and MoNE are conducted in conjunction with one another. Consequently, the IB-DP enacted curriculum is shaped by the cultural context.

7.1.2. Influence of Cultural Aspects

According to Williams *et al.*, (2016), disciplinarity can be conceptualized as a multifaceted and nested system, where different forms of inquiry are situated at one or another level of complexity within the inquiry process. This complexity can be categorized into five distinct forms: mono-, multi-, inter-, trans-, and meta-disciplinarity. It is proposed that the term "inter" involves a form of hybridization between the disciplines, as exemplified by the transition from chemistry to biochemistry. Conversely, the term "trans" implies a transcendent quality, whereby the disciplines are subsumed within a unified problem-solving enterprise, as evidenced by the emergence of a new mathematical approach to gambling odds. Finally, in meta-disciplinarity, the root disciplines are perceived in their interrelationship and distinction. Although the potential for making connections with different disciplines in mathematics teaching is considerable due to the nature of mathematics, the connections with other disciplines are often made in a cursory manner in the teaching of many subjects. Similarly, the integration of the history of mathematics into lessons can be a powerful method of teaching mathematics by modelling how humanity has developed mathematical knowledge. However, it is limited to its use as a tool and cannot be applied in a way that will guide students' learning of mathematics when they go beyond superficial examples. The primary challenge in integrating mathematics with other disciplines is integration of mathematics with other disciplines in the teaching of mathematics which is affected by cultural aspects. Williams *et al.*, (2016) propose a three-fold classification at this juncture: the integration of mathematics into the teaching of another discipline, the integration of another discipline into the mathematics course, and problem- or project-centered integration.

In this study, following the initial semi-structured interview with eight teachers, they were divided into two groups: those at the multidisciplinary level and those at the becoming interdisciplinary level in the process. Therefore, becoming interdisciplinary level emerged from the data collected which is not a level of complexity within the inquiry process of Williams and Roth (2019). Moreover, this is because teachers at the

becoming interdisciplinary level are distinguished in terms of their implementations. This differentiation emerged because of the way they use interdisciplinary approaches while teaching exponential functions. According to Aslan-Tutak (2020), a multidisciplinary approach to explaining the function involves referencing another discipline at the context or theme level within the mathematics course, with the problems solved. Furthermore, an interdisciplinary approach to explaining the function entails incorporating real-world question solutions and establishing a relationship between mathematical modeling activities in the mathematics course and other disciplines. This approach also entails seeking answers to questions that are meaningful for both disciplines in solving a problem. The findings of this study indicate that cultural differentiation emerged because the way they use interdisciplinary approaches differs when moving from conceptual understanding and procedural fluency to the nature of mathematics. Three of the teachers employed interdisciplinarity in their instruction to teach exponential function whereas one teacher used interdisciplinarity as a tool to facilitate pure mathematics teaching.

7.2. Influence of Instructional Approaches

Interdisciplinary instruction is one of the main concerns of the IB-DP curriculum in terms of both instruction and assessment processes. This study revealed that IB-DP mathematics teachers employ the technique of "mathematical modelling" to facilitate interdisciplinary and interdisciplinary thinking in mathematics lessons by using investigation activities to begin a new topic. This approach is discussed in the literature as one of the many challenges that educators face is how to engage students in authentic problem-solving involving complex systems within an interdisciplinary context (Aslan-Tutak, 2020). One approach is through mathematical modelling, which involves cycles of model construction, evaluation, and revision. This approach is fundamental to mathematical and scientific understanding and to the professional practice of mathematicians and scientists (English, 2009). Modelling is not limited to the domains of mathematics and science. Other disciplines, including engineering, technology, economics, social and environmental science, and the arts, have also made significant

contributions to the development of powerful mathematical models that are employed in the resolution of a diverse range of complex problems (Lesh and Sriraman, 2005; Sriraman and Dhal, 2008). Therefore, the concept of interdisciplinary mathematics learning and teaching should not be limited to the fields of science, technology, engineering, and mathematics (STEM). It can encompass a multitude of disciplines within the curriculum. Whether it is in the arts, as in STEAM, or in the humanities or sports, the crossing of traditional boundaries between disciplines often depends on the teacher's knowledge and preferences. The terms "models" and "modelling" have been used in various ways in the literature, including in reference to solving word problems, conducting mathematical simulations, creating representations of problem situations including constructing explanations of natural phenomena, and creating internal, psychological representations while solving a particular problem (English, 2009). A focus on modelling differs from existing approaches to the teaching of mathematics in the classroom. Firstly, the quantities and operations that are needed to mathematize realistic situations often exceed what is taught traditionally in school mathematics. The types of quantities needed in realistic situations include accumulations, probabilities, frequencies, ranks, and vectors, while the operations needed include sorting, organizing, selecting, quantifying, weighting, and transforming large datasets (Doerr and English, 2001; English, 2006; Lesh *et al.*, 2003). As indicated, modelling problems provide students with opportunities to generate these important constructs for themselves. Secondly, modelling problems offer richer learning experiences than the standard classroom word problems which means "*concept-then-word proble*", (Hamilton, 2007, p.4). The solution of such word problems typically involves a one- or two-step process of mapping problem information onto arithmetic quantities and operations. Hence, mathematical modelling offers an interdisciplinary learning context. In this current study, the common point in interdisciplinary mathematics activities, which are inquiry activities for IB-DP mathematics teachers, is that students experience the mathematization process in the context of different disciplines. Students need to be able to use mathematics to interpret, make sense of, and draw conclusions from a given situation (Aslan-Tutak, 2020). Although there are different approaches to teaching mathematical modelling, three basic elements of the process are common to these approaches: mathematizing

a given real-world situation, generating a solution with the mathematical model, and interpreting the solution found in a real-world situation. In activities that reflect this cyclical structure of mathematical modelling, students are expected to engage, question, infer, and produce mathematics. The real-life situations that are the starting point for mathematical modelling activities may consist of problems from other disciplines, and in this context, interdisciplinary connections can be made in mathematics education (Aslan-Tutak, 2020). The mathematical model serves as the foundation for interdisciplinary thinking and interdisciplinarity.

The four IB-DP mathematics teachers who are at the becoming interdisciplinary level ensure this through the investigation activities they use in their lessons to start the topic of exponential function. These activities are designed to target students' skills through daily life examples that require students to use knowledge from more than one discipline. The mathematical modelling activities provided in the investigation activities aim to create an introduction to the concept and conceptual understanding rather than skill-based activities. The interdisciplinary implementation of the four teachers is related to their understanding of conceptual understanding and procedural fluency of exponential function. The IB-DP mathematics teachers employ mathematical modelling and conceptual-based learning with mathematical modelling, capitalizing on the interdisciplinary relationships between mathematics and other disciplines through investigation activities to introduce the subject matter by elucidating the fundamental concepts of the mathematical discipline. By doing that, the IB-DP mathematics teachers highlight conceptual understanding rather than skill-based understanding which is the real-life concern of teachers about students.

This means that teachers who apply interdisciplinarity from the IB-DP curriculum do so by basing it on conceptual understanding and procedural fluency. While introducing exponential function with the help of investigation activity, interdisciplinarity emerged in the in-class instructions while supporting the mathematical modelling used. Therefore, conceptual understanding and procedural fluency emerged in class instructions. On the other hand, there are some discrepancies in the implementation

of interdisciplinary approaches between teachers in terms of in-class instruction. These discrepancies are attributable to the distinct characteristics of the nature of schools because the nature and culture of schools vary considerably from one institution to another. This is due to a number of factors, including the approaches, cultures, and perspectives of each school, the type of schools, and the teachers' perspectives who work within them. The present study revealed that the implementation of the educational program differs according to the type of school, the profile of the students taught, and the mode of operation of the teaching staff, whether they work individually or in teams. The nature of private schools, for instance, tends to embrace progress through teamwork, which is reflected in their approach to the IB Diploma Programme (IB-DP). This has led to a culture of collaboration among teachers which has an impact on instruction in class. In contrast, teachers at state schools are expected to work independently, which limits the extent to which the school culture and approach can influence their work. Also, in Turkey, only students from state high schools who demonstrate high academic performance are selected for the IB-DP whereas moderate academically achieved students are selected for IB-DP in private schools. This is another impact on instruction in class which stems from the implementation of interdisciplinary approaches.

7.3. Influence on Assessment Approaches

As Sackney (2007) asserts, the "Effective Schools" process has proven to be a resilient and enduring approach to school improvement, establishing itself as a benchmark for educational institutions seeking to enhance student outcomes. In terms of elucidating the efficacy of educational institutions and potential avenues for enhancement, the cultural dimension represents a pivotal factor (Suárez-Ortega, *et al.*, 2012). The nature of the educational institution also affects the assessment process of curricula. Assessment is a method of determining how a school can implement changes that will enhance the learning of all students through the teaching and learning processes, the school's organizational structures, and by applying gained knowledge to improve the school. Assessment types assist in determining the most effective path forward,

with the objective of facilitating change in order to achieve educational objectives in the most effective manner (Murillo, 2002). Internal assessment, or in other words, coursework, has been incorporated into various international secondary education programs, including the Advanced Placement (AP), International General Certificate of Secondary Education (IGCSE), and IB-DP (Metli, *et al.*, 2023). These programs afford students the opportunity to assume responsibility for their own learning, enhance their communication skills, and engage in independent research (Bullock, *et al.*, 2002). Moreover, internal assessment which is coursework has been implemented to facilitate the assessment of positive achievement (Tattersall, 1994) and to measure skills that cannot be assessed through formal written examinations (Elwood, 1999). Consequently, internal assessment has been regarded as a formative assessment, whereby it serves not only to facilitate students' learning processes but also to assess their general academic performance. In such cases, the performance of students in internal assessments is taken into account in the calculation of their final scores in external assessments, as is the case in some international education programmes, such as the IB-DP. The extended essay (EE) is another mandatory requirement of assessments in the IB-DP curriculum for students to engage in independent research through an in-depth study of a question pertaining to one of the subjects they are studying (Tarc and Beatty, 2012). Findings of this study show that IB-DP mathematics Teachers are more comfortable with the assessment procedure processes of IA and EE because they are not constrained by external factors so, they can manage the processes and guide students by using interdisciplinarity. Nevertheless, the prevailing culture of the educational institution exerts a significant influence on the manner in which teachers direct and oversee the assessment of students. This is despite the fact that teachers are permitted to engage in interdisciplinary assessment and are becoming interdisciplinary level.

Based on the findings of this study, mathematics teachers who work at state schools use the available online resources of IB-DP to construct a base assessment process that adheres to a thematic progression of water. On the other hand, private school teachers follow a way of what the team decided for the assessment process by giving an outline of the assessment processes of IA and EE. The reason for such difference might

be teachers in private schools having a well-established materials repository that has been conducted over the years by the mathematics IB-DP team however for the state schools there is individual work, so they make decisions by themselves. Even though teachers at the becoming interdisciplinary level have completed their undergraduate studies in English medium instruction universities and possess the ability to understand and interpret global resources when they have access to them, the usage of those resources is different. The primary distinction between these two groups of teachers is the nature of the educational institutions in which they work. For state schools, they teach to higher achieved students so, these teachers provide guidance to students throughout the assessment process, utilizing the resources they have prepared individually and those available online in an efficient manner. Conversely, private school teachers work with a mixed-ability group with well-established resources that have been made up over the years by the mathematics team of the school.

In literature, the emphasis placed on student activities in any given curriculum places a corresponding responsibility on the teacher as a planner and director of learning activities. The teacher is not only a disseminator of knowledge; s/he is also a director of learning. S/He is a knowledgeable planner, leader, and director of activities as well as content learning. In order to fulfill this role, it is essential for the teacher to have a thorough understanding of the objectives of the curriculum and to possess adequate subject-matter background. A significant portion of the teacher's time is spent in preparing for the instructional process. The selection of curricular materials from the curriculum places an additional responsibility on the teacher. The teacher who utilizes materials from these curriculum projects assumes new responsibilities in the evaluation and testing of student achievement (Choppin *et al.*, 2022).

The external assessment is another component of the assessment part of the IB-DP curriculum. The external assessment affects the instruction of teachers because one of the aims of teachers is to prepare students for the external assessment process. Therefore, external assessment can affect the instructional process of the exponential function. However, in this study, the external assessment and its process are not

included because it is not a curriculum component in which teachers can intervene in the process. In this study, findings show that the IB-DP curriculum resources affect the IA and EE assessment procedures of teachers who are becoming interdisciplinary level. Therefore, these four teachers' approaches to assessment can be considered as interdisciplinary level while the instruction approaches can be considered as staying at becoming interdisciplinary level.

8. LIMITATIONS AND SUGGESTION

In this section, the limitations of the current study and suggestions for further studies are discussed. This study aimed to gain insight into the manner in which IB-DP mathematics teachers in Turkey integrate interdisciplinary into their teaching and assessment practices. During the study, there were some limitations. Due to the one particular course of one curriculum and the study's qualitative approach, the number of participants was limited. The relatively small number of IB-DP mathematics teachers, with only eight participating in this study, represents limitation. Therefore, the findings of this study should not be considered for generalization. In further research, the perspectives of IB-DP teachers' interdisciplinarity for their instructions and assessment process should be examined with a higher number of participants to extend the result of study.

Additionally, the exclusive focus on IB-DP mathematics teachers in Istanbul, Turkey, further constrains the generalizability of the findings. The manner in which the teachers examined interdisciplinarity through the subject of exponential function was investigated and their teaching processes were examined through semi-structured interviews. Consequently, this study can be conducted again to examine how teachers teaching other disciplines in various locations in Turkey implement the subject of interdisciplinarity in their instruction and assessment processes and to examine their lecture processes.

The last limitation of this study was that it was not possible to observe teachers' interdisciplinary instruction and assessment processes. The data source of this study is limited with interviews and instructional resources. Consequently, no data could be obtained about the role of the exponential function in other disciplines and how teachers teach the exponential function in the classroom with an interdisciplinary approach. Similarly, no data could be obtained on how teachers used the interdisciplinary approach in the IA and EE process and how they guided students through the assess-

ment process they carried out in collaboration with the students. Consequently, future research may be conducted by examining the one-to-one interactions between teachers and students in the lecture and assessment processes.

REFERENCES

Arnold, R.D. and J.P. Wade, 2015, "A Definition of Systems Thinking: A Systems Approach", *Procedia Computer Science*, Vol. 44, No. 1, pp. 669-678.

Aslan-Tutak F., 2020, *Matematik Eğitiminde Disiplinlerarasi Etkinlikler ve STEM Eğitimi*, In Y. Dede, M.F. Doğan and F. Aslan-Tutak (Eds.) Matematik Eğitiminde Etkinlikler ve Uygulamaları, Ankara: PEGEM Akademi.

Aspers, P. and U. Corte, 2019, "What is Qualitative in Qualitative Research", *Qualitative Sociology*, Vol. 42, No.1, pp. 139-160.

Biggs, J.B., 1993, "From Theory To Practice: A Cognitive Systems Approach", *Higher Education Research and Development*, Vol. 12, No. 1, pp. 73-85.

Biggs, J.B., 2003, *Teaching for Quality Learning At University: What the Student Does*, Open University Press, Buckingham.

Biggs, J. and C. Tang, 2011, *Teaching for Quality Learning at University*, Mcgraw-Hill Education, United Kingdom.

Brown, M., 2022, "What is Interdisciplinary Mathematics, Learner", https://www.learner.com/ blog/ what- is- interdisciplinary mathematics, accessed on October 21, 2024.

Bullock, K., K. Bishop, S. Martin, and A. Reid, 2002, "Learning from Coursework in English and Geography", *Cambridge Journal of Education*, Vol. 32, No. 3, pp. 325-340.

Choppin, J., A. Roth McDuffie, C. Drake and J. Davis, 2022, "The role of Instructional Materials in the Relationship Between the Official Curriculum and the Enacted

Curriculum", *Mathematical Thinking and Learning*, Vol. 24, No. 2, pp. 123-148.

Clancey, W.J., 1995, A Tutorial on Situated Learning, *In Proceedings of the International Conference on Computers and Education*, Taiwan, Vol. 1, No. 1, pp. 49-70.

Cohen, D.K., S.W. Raudenbush and D.L. Ball, 2003, "Resources Instruction, and Research", *Educational Evaluation and Policy Analysis*, Vol. 25, No. 2, pp. 119-142,.

Creswell, J.W. and C.N. Poth, 2016, *Qualitative Inquiry and Research Design: Choosing Among Five Approaches*, Sage Publications, Washington.

Czerniak, C.M., W.B. Weber Jr, A. Sandmann and J. Ahern, 1999, "A Literature Review of Science and Mathematics Integration", *School Science and Mathematics*, Vol. 99, No. 8, pp. 421-430.

D'Ambrosio, U., 1981, "Uniting Reality And Action: A Holistic Approach to Mathematics Education, Teaching Teachers", *Teaching Students: Reflections on Mathematical Education*, Vol. 1, No. 1, pp.33-42.

Doerr, H. and L. English, 2001, *A Modelling Perspective on Students' Learning Through Data Analysis, In Proceedings of the 25th Conference on the International Group for the Psychology of Mathematics Education* (pp. 361-368). Freudenthal Institute, Utrecht University, Utrecht.

Doig, B., J. Williams, D. Swanson, R. Borromeo Ferri and P. Drake, 2019, *Interdisciplinary Mathematics Education: The State of The Art and Beyond*, ResearchGate, Hamburg.

Diploma Programme Curriculum, 2023, "Diploma Programme Curriculum" https:// www. ibo. org/ programmes/ diploma- programme/ curriculum/, accessed on May

20, 2024

Dyehouse, M., D. Bennett, J. Harbor, A. Childress and M. Dark, 2009, "A Comparison of Linear and Systems Thinking Approaches for Program Evaluation Illustrated Using the Indiana Interdisciplinary GK-12", *Evaluation and Program Planning*, Vol. 32, No. 3, pp. 187-196.

Elwood, J., 1999, "Equity Issues in Performance Assessment: The Contribution of Teacher-Assessed Coursework to Gender-Related Differences In Examination Performance", *Educational Research and Evaluation*, Vol. 5, No. 4, pp. 321344-321360.

English, L.D. and J.J. Watters, 2005, "Mathematical Modelling in the Early School Years", *Mathematics Education Research Journal*, Vol. 16, No. 3, pp. 58-70.

English, L.D., 2009, "Promoting Interdisciplinarity Through Mathematical Modelling", *The International Journal on Mathematics Education*, Vol. 41, No. 1, pp. 161-181.

Ernest, P., 2002, " in Mathematics Education", *Philosophy of Mathematics Education Journal*, Vol. 15, No. 1, pp. 1-16.

Geiger, V., H. Forgasz and M. Goos, 2015a, "A Critical Orientation to Numeracy Across the Curriculum", *The International Journal on Mathematics Education*, Vol. 47, No. 4, pp. 611-624.

Gerring, J., 2004, "What is a Case Study and What is it Good For?", *American Political Science Review*, Vol. 98, No. 2, pp. 341-354.

Goldman, S., M. Carroll and A. Royalty, 2009, "Destination, Imagination and the Fires Within: Design Thinking in a Middle School Classroom", *In Proceedings of the Seventh Association for Computing Machinery Conference On Creativity and Cognition*, Chen.

Guba, E.G., 1981, "Criteria for Assessing the Trustworthiness of Naturalistic Inquiries", *Ectj*, Vol. 29, NO. 2, pp. 75-91.

Hamilton, E., 2007, *What Changes are Needed in the Kind of Problem Solving Situations where Mathematical Thinking is Needed Beyond School?*, In R. Lesh, E. Hamilton and J. Kaput (Eds.), Foundations For The Future In Mathematics Education, Lawrence Erlbaum, Mahwah.

Handal, B. and J. Bobis, 2004, "Teaching Mathematics Thematically: Teachers' Perspectives", *Mathematics Education Research Journal*, Vol. 16, No. 1, pp. 3-18.

Handal, B. and A. Herrington, 2003, "Mathematics Teachers' Beliefs and Curriculum Reform", *Mathematics Education Research Journal*, Vol. 15, No. 1, pp. 59-69.

Hazelkorn, E., C. Ryan, Y. Beernaert, C. Constantinou, L. Deca, M. Grangeat, M. Karikorpi A. Lazoudis, R. Pinto, M. Welzel-Beruer, 2015, *Science Education for Responsible Citizenship: Report to the European Commission of the Expert Group on Science Education*, Office of the European Union, Luxembourg.

Hill, I. and S. Saxton, 2014, "The International Baccalaureate (Ib) Programme: an International Gateway to Higher Education and Beyond", *Higher Learning Research Communications*, Vol. 4, No. 3, pp. 42-52.

Hotăran, I., 2009, "Silo Effect vs. Supply Chain Effect", *Revista De Management Comparat Internațional*, Vol. 10, No.1, pp. 216-221.

Hume, A. and R. Coll, 2010, "Authentic Student Inquiry: The Mismatch Between the Intended Curriculum and The Student-Experienced Curriculum", *Research in Science and Technological Education*, Vol. 28, No. 1, pp. 43-62.

International Baccalaureate Organization, 2023, "Diploma Programme: Theory of

Knowledge Guide", http://www.ibo.org, accessed on May 22, 2024, accessed on May 19, 2024.

International Baccalaureate Organization, 2023, "Creativity, Action", http:// www. ibo. org, accessed on May 22, 2024, accessed on May 20, 2024.

International Baccalaureate Organization, 2018, "Extended Essay Guide", https:// ibpublishing. ibo. org/ extendedessay/ apps/ dpapp/ index .html? doc= d- 0- eeyyy- gui- 1602- 1- e, accessed on May 22, 2024.

International Baccalaureate Organization, 2021, "Interdisciplinary Learning in the International Baccalaureate", https://www.ibo. org/ research/ curriculum- research/ cross- programme/ interdisciplinary- learning- in- the- international-baccalaureate - 2021/, accessed on May 22, 2024.

International Baccalaureate Organization, 2021, "Mathematics: Analysis and Approaches Guide", https:// www. ibo. org/ programmes/ diploma- programme/ curriculum/ mathematics/, accessed on May 22, 2024..

International Baccalaureate Organization, 2023, "why DP Schoolwide", https://www. ibo. org/ ib- schoolwide- adoption/ a- more- inclusive- ib/ why-dp- schoolwide/, accessed on May 22, 2024.

Klaassen, R.G., 2018, "Interdisciplinary Education: A Case Study", *European Journal of Engineering Education*, Vol. 43, No. 6, pp. 842-859.

Khandkar, S.H., 2009, "Open Coding", *University of Calgary*, Vol. 23, No. 1, pp. 2009-2025.

Klein, J.T., 2021, *Beyond Interdisciplinarity: Boundary work, Communication and Collaboration*, Oxford University Press, New York.

Knight, D.B., L.R. Lattuca, E.W. Kimball and R.D. Reason, 2013, "Understanding Interdisciplinarity: Curricular and Organizational Features of Undergraduate Interdisciplinary Programs", *Innovative Higher Education*, Vol. 38, No. 1, pp. 143-158.

Kurz, A., S.N. Elliott, J.H. Wehby and J.L. Smithson, 2010, "Alignment of the Intended, Planned, and Enacted Curriculum in General and Special Education and its Relation to Student Achievement", *The Journal of Special Education*, Vol. 44, No. 3, pp. 131-145.

Laursen, B.K., N. Motzer and K.J. Anderson, 2022, "Pathways for Assessing Interdisciplinarity: A Systematic Review", *Research Evaluation*, Vol. 31, No. 3, pp. 326-343.

Lesh, R., K. Cramer, H.M. Doerr, T. Post and J.S. Zawojewski, 2003, *Model Development Sequences*, In Beyond Constructivism, Routledge.

Lesh, R. and B. Sriraman, 2005, *John Dewey Revisited-Pragmatism and the Models-Modeling Perspective on Mathematical Learning, In Proceedings of the 1st International Symposium on Mathematics and its Connections to the Arts and Sciences* (pp. 32-51), Pedagogical University of Schwaebisch Gmuend, Hildesheim.

Lincoln, Y.S. and E.G. Guba, 1985, *Naturalistic Inquiry*, Sage, Lincoln.

Lou, Y. and J. Ma, 2015, A 3D "T-shaped Design Education Framework", *Arts, Research, Innovation and Society*, Vol. 1, No.1, pp.123-136.

Metli, A., O. Özcan and D. Akış, 2023, "Unveiling the Relationship Between Internal Assessment and External Assessment in the International Baccalaureate Diploma Program", *Anadolu Üniversitesi Eğitim Fakültesi Dergisi*, Vol. 7, No. 2, pp. 386-403.

Maass, K., V. Geiger, M.R. Ariza and M. Goos, 2019, "The Role of Mathematics in Interdisciplinary STEM Education", *The International Journal on Mathematics Education*, Vol. 51, No. 1, pp. 869-884.

Manlove, S., 2021, *Interdisciplinary Learning in the International Baccalaureate*, IB Research Department: Ecctis.

Merriam, S.B., 2009, *Qualitative Research: A Guide to Design and Implementation* (3rd Ed), Josseybass, San Francisco.

Ministry of National Education, 2021, "Ministry of National Education, General Directorate of Secondary Education, Mission and vision", https:// ogm. meb. gov. tr /www /misyon- ve- vizyon/ icerik/ 1281, accessed on April 01, 2024.

Ministry of National Education, 2023, "Weekly High School Schedules", https:// ttkb meb. gov. tr/ www/ haftalik- ders- cizelgeleri/ kategori/7, accessed on April 10, 2024.

Moore, J.E., A. Mascarenhas, J. Bain, and S.E. Straus, 2017, "Developing A Comprehensive Definition of Sustainability", *Implementation Science*, Vol. 12, No. 1, pp. 1-8.

Murillo, F.J. 2002, "La Mejora De La Escuela: Concepto Y Caracterización, In La Mejora De La Escuela", *Un Cambio De Mirada, ResearchGate*, Vol. 1, No. 1, pp. 15-51.

Middle Years Programme Curriculum 2023, "International Baccalaureate", https://www. ibo. org/ programmes/ middle- years- programme/ curriculum/, accessed on April 15, 2024.

Nae, H.J., 2017, "An Interdisciplinary Design Education Framework", *The Design*

Journal, 20, No. 1, pp. S835-S847.

National Council of Teachers of Mathematics, 2010, *Developing Essential Understanding of Functions*, The National council of Teachers of Mathematics, Reston.

Nissani, M.,1994, "Psychological, Historical, and Ethical Reflections on the Mendelian Paradox", *Perspectives in Biology and Medicine*, Vol. 37, No. 2, pp. 182-196.

Nissani, M., 1995, "Fruits, Salads, and Smoothies: A Working Definition of Interdisciplinarity", *The Journal of Educational Thought (JET)/Revue De La Pensée Éducative*, Vol. 1, No. 1, pp.121-128.

Organisation for Economic Co-operation and Development, 2020, "Curriculum (Re) Design A Series of Thematic Reports from fhe OECD Education 2030 Project Overview Brochure", https:// www. oecd. org/ education/ 2030- project/ contact/ brochure- thematic- reportson- curriculum- redesign.pdf, accessed on April 15, 2024.

Organisation for Economic Co-operation and Development, 2019, "Future of Education and Skills 2030: Conceptual Learning Framework", https:// www. oecd. org/ education/ 2030- project/ teaching- and- learning/ learning/ knowledge/ Knowledge-for- 2030- concept- note. pdf, accessed on April 15, 2024.

Patton, M.Q., 1990, *Qualitative Evaluation and Research Methods*, Sage Publications, Thousand Oaks.

Porter, A.C. and J.L. Smithson, 2002, *Alignment of Assessments, Standards and Instruction Using Curriculum Indicator Data*, Paper Presented at the Annual Meeting of the American Educational Research Association, New Orleans.

Primary Years Programme Curriculum Framework, 2023, "Primary Years Programme

Curriculum", https:// www. ibo. org/ programmes/ primary- years- programme/ curriculum/, accessed on April 20, 2024.

Sackney, L., 2007, "History of the School Effectiveness and Improvement Movement in Canada Over the Past 25 Years", *In International Handbook of School Effectiveness and Improvement*, Vol. 17, No. 2, pp. 167-82.

Spelt, E.J., H.J. Biemans, H. Tobi, P.A. Luning and M. Mulder, 2009, "Teaching and Learning in Interdisciplinary Higher Education: A Systematic Review Educational", *Psychology Review*, Vol. 21, No. 4, pp. 365-378.

Spelt, E.J., P.A. Luning, M.A. van, Boekel and M. Mulder, 2015, "Constructively Aligned Teaching and Learning in Higher Education in Engineering: What Do Students Perceive as Contributing to the Learning of Interdisciplinary Thinking", *European Journal of Engineering Education*, Vol. 40, No. 5, pp. 459-475.

Sriraman, B. and B. Dahl Søndergaard, 2009, "On Bringing Interdisciplinary Ideas to Gifted Education", *International Handbook on Giftedness*, Vol. 1, No. 1, pp. 1235-1256.

Suárez-Ortega, M., B. Ballesteros-Velázquez and B. Malik-Liévano, 2012, "Educational Achievement and Effective Schools: Examples of Best Practice", *Intercultural Education*, Vol. 23, No. 1, pp. 1-13.

Swetz, F. and J.S. Hartzler, 1991, *Mathematical Modeling in the Secondary School Curriculum.* National Council of Teachers of Mathematics, Inc., 1906 Association Dr., Reston.

Tarc, P. and L. Beatty, 2012, "The Emergence of The International Baccalaureate Diploma in Ontario: Diffusion, Pilot Study and Prospective Research", *Canadian Journal of Education/Revue Canadienne De L'éducation*, Vol. 35, No. 4, pp. 341-

375.

Tattersall, K., 1994, "The role and Functions of Public Examinations, Assessment in Education: Principles", *Policy and Practice*, Vol. 1, No. 3, pp. 293-304.

Van Merriënboer, J.J.G., 1997, *Training Complex Cognitive Skills: A Four-Component Instructional Design Model for Technical Training*, Englewood Cliffs: Educational Technology, Vatican.

Yarker, M.B.S. Park, 2012, "Analysis of Teaching Resources for Implementing an Interdisciplinary Approach in the K-12 Classroom", *Eurasia Journal of Mathematics, Science and Technology Education*, Vol. 8, No. 4, pp. 223-232.

Williams, J., W.M. Roth, D. Swanson, B. Doig, S. Groves, M. Omuvwie and N. Mousoulides, 2016, *Interdisciplinary Mathematics Education*, Springer Nature, Hamburg.

Williams, J. and W.M. Roth, 2019, "Theoretical Perspectives on Interdisciplinary Mathematics Education", *Interdisciplinary Mathematics Education: The State of the Art and Beyond*, Vol. 1, No. 1, pp 13-34.

Yin, R.K. 2009, *Case Study Research: Design and Methods* (4 ed.). Sage, Los Angeles.

Yin, R. K., 2014, *Case Study Research: Design And Method* (5th Ed.), Sage, Thousand Oaks.

APPENDIX A: FIRST LEVEL OF SEMI-STRUCTURED INTERVIEWS

In order to gain insight into the interdisciplinary perspectives of teachers, the first-level semi-structured interview questions were designed.

1. Can you tell us about yourself? Which university and which program did you graduate from? So, did you have a master's or doctoral degree?

2. How many years have you been teaching mathematics?

a. How long have you been teaching IB-DP mathematics curriculum? Can you tell us about your experiences?

b. How did you decide to become an IB Mathematics teacher? Are you satisfied?

3. In your opinion, how can interdisciplinary thinking be defined? Can you explain with an example?

4. If you were to design an instruction that aims to develop students' interdisciplinary thinking skills, what would you pay attention to?

5. What do you think is the role of the applied curriculum in supporting the development of students' interdisciplinary thinking skills?

6. When you consider the IB-DP (SL or HL) mathematics program you are applying

a. To what extent do you think it is suitable for interdisciplinary teaching?

b. For what features do you think it is suitable?

7. How do you apply the interdisciplinary teaching approach in your teaching process?

a. How much do you practice?

8. Is there anything you would like to add?

APPENDIX B: SECOND LEVEL OF SEMI-STRUCTURED INTERVIEWS

In order to gain a deep insight into the interdisciplinary perspectives of teachers in terms of instruction and assessment processes, the second-level semi-structured interview questions were designed.

1. Have you covered the topic of exponential functions in your current IB class? When did you teach?

2. Teaching the exponential function subject in the program

a. How did you plan it?

b. How did you implement it?

3. Have you had the opportunity to handle mathematics with an interdisciplinary approach to teaching exponential functions? What did you do?

4. Can you share examples of lecture materials, lesson plans, etc. regarding your exponential function teaching?

5. How did you plan/carry out the application process of the extended essay (EE) evaluation tool in the program?

a. Did you aim to apply an interdisciplinary approach to mathematics? How did you handle it?

6. Could you briefly tell us how you planned/implemented the implementation process of the internal assessment (IA) evaluation tool included in the program?

a. Did you aim to apply an interdisciplinary approach to mathematics? How did you handle it?

7. Is there anything you would like to add?

APPENDIX C: INSTITUTIONAL ETHICAL APPROVAL FROM BOGAZICI UNIVERSITY

T.C.
BOĞAZİÇİ ÜNİVERSİTESİ REKTÖRLÜĞÜ
Fen Bilimleri ve Mühendislik Alanları İnsan Araştırmaları Etik Kurulu (Fminarek)

Sayı : E-84391427-050.01.04-168095 21.02.2024
Konu : 2023/30 Kayıt no'lu başvurunuz hakkında

Sayın Doç. Dr. Fatma ASLAN TUTAK

"Uluslararası Bakalorya Diploma Programı Matematik ve Fen Bilimleri Öğretmenlerinin Disiplinlerarasılık Anlayışı ve Öğretim Yaklaşımlarının İncelenmesi" başlıklı projeniz ile Boğaziçi Üniversitesi Fen Bilimleri ve Mühendislik Alanları İnsan Araştırmaları Etik Kurulu (FMİNAREK)'e yaptığınız 2023/30 kayıt numaralı başvuru 05.02.2024 tarihli ve 2024/02 No.lu kurul toplantısında incelenerek etik onay verilmesi uygun bulunmuştur.

Bu karar tüm üyelerin toplantıya on-line olarak katılımıyla ve oybirliği ile alınmıştır. Onay mektubu tüm üyeler adına Komisyon Başkanı tarafından e-imzalanmıştır. Bilginize sunarız.

Saygılarımızla,

Prof. Dr. Tınaz EKİM AŞICI
Kurul Başkanı

Bu belge, güvenli elektronik imza ile imzalanmıştır.
Belge Doğrulama Kodu : 0IMI-7D0G-0K7U Belge Doğrulama Adresi : https://www.turkiye.gov.tr/bogazici-universitesi-ebys

Telefon No: Fax No:
e-Posta: İnternet Adresi: www.bogazici.edu.tr
Kep Adresi: bogaziciuniversitesi@hs01.kep.tr

Bilgi İçin:Nurşen MUNAR
Mühendis
Telefon No:

Figure C.1. Ethics committee.

APPENDIX D: INFORMED CONSENT FORM

T.C.
BOĞAZİÇİ ÜNİVERSİTESİ
FEN BİLİMLERİ VE MÜHENDİSLİK ALANLARI
İNSAN ARAŞTIRMALARI ETIK KURULU
KATILIMCI BİLGİ ve ONAM FORMU

Araştırmanın adı: Uluslararası Bakalorya Diploma Programı Matematik ve Fen Bilimleri Öğretmenlerinin Disiplinlerarasılık Anlayışı ve Öğretim Yaklaşımlarının İncelenmesi

Proje Yürütücüsü/Araştırmacının adı: Doç. Dr. Fatma ASLAN TUTAK/ Simge AKBAL
Adresi: Boğaziçi Üniversitesi, Eğitim Fakültesi, No:510, Bebek 34342, İstanbul
E-mail adresi: simge.akbal@boun.edu.tr
Telefonu: 0553 132 1614

Sayın öğretmen/öğretmen adayı,

Boğaziçi Üniversitesi Matematik ve Fen Bilimleri Eğitimi Bölümü yüksek lisans öğrencisi Simge Akbal "Uluslararası Bakalorya Diploma Programı Matematik ve Fen Bilimleri Öğretmenlerinin Disiplinlerarasılık Anlayışı ve Öğretim Yaklaşımlarının İncelenmesi" adı altında bilimsel bir araştırma projesi yürütmektedir. Bu araştırmanın amacı, Uluslararası Bakalorya Diploma Programını uygulayan öğretmenlerin ders anlatımlarında disiplinlerarası öğretim yaklaşımını nasıl kullandığını incelemektir. Bu araştırmada bize yardımcı olmanız için siz öğretim görevlilerini de projemize davet ediyoruz. Kararınızdan önce araştırma hakkında sizi bilgilendirmek istiyoruz. Bu bilgileri okuduktan sonra araştırmaya katılmak isterseniz lütfen bu formu imzalayıp kapalı bir zarf içinde bize ulaştırınız.

Bu araştırmaya katılmayı kabul ettiğiniz takdirde disiplinlerarası öğretim yaklaşımı hakkında bireysel bir mülakat yapmayı rica edeceğiz. Görüşmemiz yaklaşık 30 dakikanızı alacaktır.
İkinci olarak, disiplinlerarası öğretim yaklaşımı içerisindeki kullandığınız aktiviteler gözlemlenecektir.

Bu araştırma bilimsel bir amaçla yapılmaktadır ve katılımcı bilgilerinin gizliliği esas tutulmaktadır. Verinin analizi ve farklı ortamlarda paylaşılmasında katılımcıların isim, okul vb. belirleyici bilgileri paylaşılmayacaktır. Toplanan elektronik ve basılı veri, araştırma projemiz süresince kilitli bir dolapta muhafaza edilip, araştırma sona erdiğinde silinecektir. Seçilmiş veri ve veri analizi sonuçları katılımcıların kimliği belirtilmeden çevrimiçi öğretim ortamları tasarımlarında veya bilimsel nitelikte yayın ve sunumlarda kullanılabilir.

Bu araştırmaya katılmak tamamen isteğe bağlıdır. Katıldığınız takdirde çalışmanın herhangi bir aşamasında herhangi bir sebep göstermeden onayınızı çekmek hakkına da sahipsiniz. Onayınızı çekmeniz sdurumunda katılımcı bilgileriniz veri listesinden silinecek ve çalışmanın ileri adımlarında kullanılmayacaktır. Bu aşamaya kadar toplanan verileriniz proje ekibi tarafından erişime açık olan depolama bulut sistemlerinde muhafaza edilecektir. Araştırmayla ilgili haklarınız konusunda Boğaziçi Üniversitesi Fen Bilimleri ve Mühendislik Alanları İnsan Araştırmaları Etik Kurulu'na (fminarek@boun.edu.tr) danışabilirsiniz.

Araştırma projesi hakkında ek bilgi almak istediğiniz takdirde lütfen Boğaziçi Üniversitesi Matematik ve Fen Bilimleri Eğitimi Bölümü yüksek lisans öğrencisi Simge Akbal ile temasa geçiniz (Telefon: 0553 132 1614, Adres: Boğaziçi Üniversitesi, Eğitim

Fakültesi, 34342 Bebek, İstanbul).

Eğer bu araştırma projesine katılmayı kabul ediyorsanız, lütfen bu formu imzalayıp kapalı bir zarf içerisinde bize geri yollayın.

Ben, (katılımcının adı) .....,

yukarıdaki metni okudum ve katılmam istenen çalışmanın kapsamını ve amacını, gönüllü olarak üzerime düşen sorumlulukları tamamen anladım. Çalışma hakkında soru sorma imkanı buldum. Bu çalışmayı istediğim zaman ve herhangi bir neden belirtmek zorunda kalmadan bırakabileceğimi ve bıraktığım takdirde herhangi bir olumsuzluk ile karşılaşmayacağımı anladım.

Bu koşullarda söz konusu araştırmaya kendi isteğimle, hiçbir baskı ve zorlama olmaksızın katılmayı kabul ediyorum.

Formun bir örneğini aldım / almak istemiyorum (bu durumda araştırmacı bu kopyayı saklar).

Katılımcının Adı-Soyadı:

.....

İmzası: .....

Adresi (varsa Telefon No, Faks No):

.....

.....

Tarih (gün/ay/yıl): ... /... /...

Araştırmacının Adı-Soyadı: Simge Akbal

İmzası:

Tarih (gün/ay/yıl): ... /... /...