



TEACHING APPLICATIONS OF MATHEMATICS IN OTHER DISCIPLINES: TEACHERS' OPINION AND PRACTICE

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Abstract. One of the main topics of mathematics education nowadays is teaching applications of mathematics in various fields, which lead in the recent decades to the development of the STEM education (Science, Technology, Engineering, and Mathematics), connecting these disciplines using transdisciplinary or interdisciplinary approaches. Applications of mathematics has become important not only from academic point of view, as helping students to understand mathematics, to apply mathematical knowledge in various contexts, and to show the utility of mathematics, but also because mathematics is an integral part of our daily lives. Teachers have an important role in this approach, so it is important to study their attitude towards teaching applications of mathematics and their experience.

The research was conducted in 2021 in Israel. The participants are 221 mathematics teachers from post primary schools. The research instrument was a questionnaire developed for this study based on the scientific literature and aimed to find out teachers' opinion about teaching applications of mathematics and their practice in integrating applications in their teaching. The questionnaire contains both closed and open questions. The responses were quantitatively and qualitatively analyzed.

The results of the study show that 42.5% of teachers in Israel are teaching applications of mathematics. Analyzing the answers given by those teachers, who teach applications of mathematics, 47% are teaching applications in physics, 47.5% integrate them in their lessons few times a semester, and 52.1% of them teaching applications through presenting it to the students. In the participants' opinion, the most important benefits of teaching applications of mathematics are arising students' interest for mathematics (44.3%) and motivating students for learning mathematics (34.8%). The most important obstacles of teaching applications of mathematics are time-constrains (30.8%) and lack of teachers' skills to teaching mathematical applications in other disciplines (24.6%).

Key Words: a ppplicationof mathematics, STEM, advantages of teaching applications, obstacles in teaching applications.

Introduction

The importance of mathematics stems from its necessity for human functioning in key areas of activity in the modern world. It is also a basis for logical-quantitative thinking, for science and technology studies and their development. Therefore, it is essential to teach applications of mathematics to correlate mathematics to real life, to consider mathematics as a domain that can help students in their personal development, and as a useful tool which can help them create special things in real life.

The main problem of mathematics education is that high school students frequently fail to connect the math they learned in the classroom with the life and modern world they live in (Nkhase, 2002). Students graduate from high school and yet are unaware that mathematical knowledge, mathematical skills, and mathematical applications are necessary for success in life, in their future studies, and in designating their careers. This can be explained by the teaching strategies used which neither expose to the student the relevance of mathematics, nor develop his thinking and understanding of the subject.

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By using these strategies, the student learns in an algorithmic and procedural way of solving exercises from the textbooks. Many students only study math because they must study and pass exams.

Showing applications of mathematics in other disciplines is very essential to instill in students the love of mathematics, to motivate them for learning it, to show them its importance in their daily lives without anxiety and reluctance. By the time, they will study it with enjoyment and desire which would lead to change their conceptions about and their attitude towards mathematics, improve their achievements in mathematics and related fields. There are many studies about mathematical application in other disciplines and STEM (Science, Technology, Engineering, and Mathematics) education, which have shown the effectiveness and importance of this type of education for both the student and the teacher.

Despite the importance and benefits, teaching applications of mathematics has also obstacles related with lack of preparedness of the teachers and students, and also some resource constrains, as time and materials for practical activities (Pinker, 1978).

In this regard, the present study intends to reveal the teachers' opinion and practice on teaching applications of mathematics in other disciplines. The research focuses on teachers' view about the benefits and obstacles of teaching applications of mathematics, plans to find out if teachers use applications of mathematics in their teaching, and to collect those teachers' methodological ideas, who use applications.

1. Theoretical Background

Chick & Stacey (2013) highlighted some aspects of teaching applications of mathematics in other fields such as engineering, finance, transportation, etc. In this case the focus is moving from mathematics to the field of the application. Solving a particular problem requires knowledge from both fields, application and mathematics at the same time as interaction occurs throughout the solution. Also, the success of the solution is evaluated in the field of the application.

The researchers further empathized that part of mathematics teaching is done in a routine fashion by solving workbook exercises and handing them over to the teacher. Teaching routine problems is related with preparing students for national tests, as in many cases these examinations use some well-defined problem types (Marchis, 2009a; Marchis 2009b), it is influenced by the problems from the textbooks and workbooks where predominantly routine problems are included (Kolovou, van den Heuvel – Panhuizen, & Bakker, 2009; Marchis, 2012), or teachers' lack of confidence in solving challenging problems (Silver et al, 2005). On the other hand, teaching mathematics is challenging and involves problems whose solutions are not easy or immediate. The emphasis should be placed on these type of the problems as they could develop students' problem-solving competence. Usually problems which connects more disciplines, in which the focus is not on the mathematics, but on the application of it in other fields, are challenging ones and they are appropriate for developing higher order thinking competencies.

Teaching applications of mathematics has many benefits. It helps the student to improve the mathematical understanding of his environment and correlate mathematics to life and the various fields of science, such as physics, chemistry, technology, economics, etc. It also motivates the student to learn mathematics with pleasure and to see its importance in his daily life and in various fields, which helps the student designate his future career.

STEM education has become a popular term in education around the world. Many countries recognize the need for manpower with adequate and appropriate knowledge and skills from STEM disciplines, which meet the challenges of the future. While STEM has attracted increased attention and numerous studies, there are still many discussions and dilemmas (Gao, Li, Shen, & Sun, 2020)

Most studies that dealt with STEM have shown great importance and effectiveness of this education and its application among teachers and students alike. For example, Yildirim and Sidekli, (2018) showed that STEM applications have a positive effect on mathematical literacy, so they have positively affected higher-order thinking skills in pupils and students as well. They also significantly

influenced students' attitudes towards mathematical studies, which led to an increase in academic motivation and academic success.

In the same matter, Cinari, Pirasai, Uzun and Erenler, (2016) showed that STEM education has a positive effect on students and teachers attitudes toward teaching mathematics, and that STEM education encourages pre-service teachers to choose their careers in the STEM field. This result is identical to the result found by researchers Bingolbali, Monaghan, and Roper (2007) in their study that the application of project-based learning that incorporate STEM influences students' positive attitudes toward STEM and their future career choices.

Maass, Geiger, Ariza, and Goos, (2019) also talked about the importance of STEM education and the central role of mathematics in this education. Researchers have emphasized that in the age of rapid technological innovation and the global challenges of the 21st century, STEM education and its application have become very important. They improve citizens personal scientific literacy and enhance international economic competition.

Maddena, Baxtera, Beauchampa, Boucharda, Habermasa, Huffa, Ladda, Pearona, and Plague (2013) highlight that a unique STEAM (Science, Technology, Engineering, Arts, and Mathematics) curriculum will be a model for educating creative scientists who can develop innovative solutions to serious global problems.

Additionally, today's industry leaders are looking for people who can "think outside the box", have creative thinking and diverse expertise and approach problems divergently.

English (2016) concludes that all the fields of STEM are important in order to teach and educate STEM, in order to make meaningful application and learning. In addition, STEM education and STEM programs combined, may encourage more students' involvement and increase their motivation to learn which leads to more enjoyment and better achievements in all the fields of STEM.

Despite the importance of learning mathematics applications and STEM education and their implementation that greatly benefit both the students and the teacher, many studies have shown that there are some obstacles in learning mathematics applications and STEM education; some of these obstacles are related to the teachers, some to the students and some to the organizations and administrators.

Obstacles related with students are their poor background in sciences to appreciate the applications, their interest which can be so diverse in a class that it is difficult to find examples of meaningful applications for each. As regarding teachers, they are not trained to be able to teach confidently applications from different disciplines. The third group of obstacles relates with the resources, as time, equipment, materials (Pinker, 1978).

The researchers mentioned that many teachers lack experience in the connection between the different STEM disciplines, they are underprepared to use STEM applications (El-Deghaidy & Mansour, 2015). Therefore, teachers must be trained to change their strategies and acquire strategies that combine math applications and STEM education. It is also necessary to teach the relevance of mathematics and show students its beauty and importance in the modern world, and to make them like it. As a result, the students' motivation will increase, and their self-confidence will enhance. By the time, this will lead to enjoyment in learning, improvement in their achievement and positively changing in their attitude towards mathematics which itself will help them designate their future careers.

2. Methodology

The research was conducted in 2021 in Israel.

2.1. Aim of the research

This study aims to find out teachers' opinion and practice on teaching applications of mathematics in other disciplines.

2.2. Research instrument

The research instrument was a questionnaire developed for this study based on the scientific literature. The questionnaire is designed for the purpose of surveying teachers' opinion and practice on teaching applications of Mathematics in other disciplines.

The questionnaire consists of two main parts: demographical and questions related with the research topic. The demographical part contains 10 questions, most of them closed. The second part contains 18 questions, from which 15 are closed questions (multiple choice, check box, scale, affirmations measured on a 5-level Likert scale) and 3 open questions.

2.3. Participants

221 mathematics teachers from Israelian post primary schools have participated in the study. The participation was voluntary. All participants answered all questions of the questionnaire.

The mean age of the participants was 41.1 years and the mean teaching experience 16 years.

The demographics of these participants are listed in the Table 1. Two quarter of the participants are female teachers, most of the participants are Arab. Almost half of the participants have BSc degree and half MSc degree. As regarding the level participants teach, almost half of them teach in middle school and the other participants in high-school.

Table 1. Demographic characteristics of participants

Variable		Frequency	Percent
Gender	Male	82	37%
	Female	139	67%
Nationality	Arab	201	91%
	Jewish	20	9%
Degree	BSc degree	99	44.8%
	MSc degree	119	53.8%
	PhD degree	3	2.4%
Level of class they teach	Middle school teachers	99	44.8%
	High school teachers	122	55.2%
Level of computer and technology control	Excellent	85	38.5%
	Good	108	48.9%
	Medium	28	12.7%
Type of school in which they teach	Theoretical	183	82.8%
	Religious	3	1.4%
	Technology	23	10.4%
	Private	12	5.4%

2.4. Data Analysis

Closed questions were quantitatively analyzed using SPSS program. The results include frequency, percentage, mean (M), and standard deviation (SD).

Open-ended questions were qualitatively analyzed using the categorical analysis.

3. Results and Discussion

3.1. Teachers' opinion about the benefits of teaching applications of Mathematics

Teachers consider important to teach applications of mathematics ($M=4.24$, $SD=0.52$ – measured on a scale from 1 (not important at all) to 5 (very important)). They were also asked to measure on a 5-level scale some benefits of teaching applications of Mathematics (Table 2). All the listed benefits are considered valid by the participants: the mean for each one is above 4 and the standard deviation is

below 0.80. The highest mean was obtained for expanding students' horizon and showing students the importance of mathematics.

Table 2. Teachers' perception about some benefits of teaching applications of Mathematics

Benefit	Mean	Standard deviation
arising students' interest for Mathematics	4.16	0.72
motivating students for learning mathematics	4.19	0.69
showing students the importance of mathematics	4.33	0.66
exercising mathematical knowledge	4.20	0.70
developing competency of using a mathematical knowledge in different context	4.31	0.60
improving achievement of students in mathematics	4.10	0.72
expanding the horizon of the student	4.34	0.63
developing a positive attitude towards mathematics	4.26	0.72

In another closed questions respondents were asked to select the most important two advantage of teaching applications of Mathematics from a given list. The three most selected advantages were the following: arising students' interest for mathematics (98 participants - 44.3%), motivating students for learning mathematics (77 participants - 34.8%), and showing to students the importance of mathematics (21 participants - 9.5%).

3.2. Teachers' practice in teaching applications of Mathematics

42.5% of the participants teach applications of Mathematics.

The age, teaching experience, and computer user skills of those who don't teach applications and those who teach applications of mathematics were compared (Table 3). Teachers that teach applications of mathematics in other disciplines have significantly higher computer-user skills than teachers who don't teaching applications of mathematics. The mean age and the mean teaching experience of those teachers who show applications is slightly higher, but there is no statistically significant difference.

Table 3. Comparing age, teaching experience and computer user skills of those don't teaching applications with those teaching applications with t-test in SPSS program

Variable	Don't teach applications		Teach applications		t	p
	M	SD	M	SD		
Age	40.3	9.6	42.1	8.9	1.3	0.17
Teaching experience	15.4	9.6	16.9	9	1.1	0.23
Computer user skills	1.9	0.66	1.5	0.64	-3	0.002

Note: computer user skills measured on 4-level scale (1=Excellent, 2= Good, 3=Medium, 4=Low).

Physics is the discipline in which applications are mostly integrated (47% of those respondents who teach applications) – see Table 4.

Table 4. Teaching applications of Mathematics in different disciplines

	Frequency	Percent
Physics	44	47%
Economics	13	13.8%
Chemistry	1	1%
Other (Technology, Graphic description, etc.)	36	38.2%

Almost half of the respondents who teach applications (47,9%) integrate them in their lessons few times a semester, and more than one quarter of them (29,8%) on a weekly basis (Table 5).

Table 5. The frequency of teaching applications of Mathematics

Frequency of teaching applications	Frequency	Percent
once a week	28	29.8%
few times a semester	45	47.9%
once a semester	8	8.5%
once a year	2	2.1%
other	11	11.7%

Participants were asked how they teach applications. Half of the surveyed teachers present it to their students (52.1%), the other half give students some tasks through they discover how they can apply the mathematical knowledge (45.7%).

As regarding examples of applications of concrete mathematical knowledge, most of the given examples are applications in physics. For example, maximum and minimum problems in studying the reflection and refraction of light, more generally in optics; movement problems. Another field of application is economics, as problems related with buying and selling goods, optimizing the profit. Technology or engineering also has a vast field for application of mathematics, for example in constructions, in calculation of areas, volumes, using integrals. Mathematics is present also in chemistry in different chemical calculations.

3.3. Obstacles of teaching applications of mathematics

Teachers who are not integrating applications in their lessons, were asked in an open question the reason why they not. The responses were qualitatively analyzed, and categories were identified in Table 6 below.

Table 6. Categorical analysis about the reasons why responses not integrating applications in their lessons

Category	Subcategory	Percentage of respondents whomentioned the Subcategory
Time-related issues	-There is no time for it in the classroom.	70%
	-Time for preparing lots of study materials.	30%
Problems related to the background of the teachers and the students.	- Students have a poor background in the sciences to understand the applications.	36%
	- Students have a poor background in the sciences to appreciate the applications.	20%
	- Teachers are unable or have no skills to teaching mathematical applications in other disciplines.	40%
	- Teachers have no confident in teaching it.	4%
Problems related to the curriculum.	- It is not included in the curriculum of mathematics.	79%
	-Applications of math not required in the exams.	21%
Planning and budget related issues	- Some applications require equipment and demonstrators.	83%
	- Applications a number of mathematical skills which are normally attained at the end of the mathematics program.	17%

Analyzing Table 6, the most frequently mentioned reason of not teaching applications are the lack of necessary equipment, the curriculum and time constrains.

Also, participants had to select from a given list the two main important obstacles of using applications in teaching Mathematics. The most 3 frequently selected obstacles are the following: time

constrains (30.8%), lack of methodological or pedagogical content knowledge of the teachers (24.6%), and curriculum constrains (15.5%).

Conclusion

This study shows that 42.5% of the surveyed teachers integrate applications of mathematics in other disciplines. Those with better computer-user skills are more open for teaching applications. Physics is the discipline in which applications are mostly integrated. Half of those integrating applications in their teaching do this few times a semester. The methodology how they teach applications are either passive, the teacher presenting it, or requiring active participation from the students, giving them some tasks through which they discover how they can apply the mathematical knowledge.

Even less than half of the respondents teach applications, most of the teachers in Israel consider that teaching applications of mathematics is very important, because applications of mathematics arouse students' interest for mathematics, motivate students for learning mathematics, and show to students the importance of mathematics.

Despite the importance of teaching applications of mathematics, there are obstacles that have been reported by the participants. The most common obstacles are the time and curriculum constrains, teachers' lack of scientific and methodological knowledge for teaching applications in other disciplines, and lack of equipments for demonstrations.

Most of the participants request that teaching applications of mathematics be part of the curriculum in Israel, and that a lot of time and resources should be devoted to this, because the benefit is very great and significant for both the student and the teacher.

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