

Teaching applications of mathematics: The effect of the intervention on the participating teachers*

Abdallah ASLI¹, Iuliana ZSOLDOS-MARCHIS^{2,*}

ABSTRACT. The purpose of this study is to examine the effect of the intervention with teaching applications of mathematics in other disciplines on teachers' attitudes towards teaching applications of mathematics. The research was conducted in the 2021-2022 school year in Israel and a two-groups pretest-posttest quasi-experimental research design was used. The participants were four classes (two of them are 11th grades and two are 12th grades) with four teachers at Al-Bukhari High School in Arraba city in northern Israel. The research instruments were three interview guides. The first interview was conducted before the intervention with all the 4 teachers and it contained 16 questions about their attitudes toward teaching mathematics and applications of mathematics. The second and third interview was similar and it was conducted during respectively after the intervention with the teachers in the experimental group. These interviews contained 5 questions related to teaching applications of mathematics in other disciplines.

The results of the study showed that teaching applications of mathematics in other disciplines has a positive effect on teachers. Before the intervention, the teachers taught using the standard method, and they rarely taught applications. The teachers were not qualified enough to teach applications of mathematics and were not aware of the advantages of teaching applications of mathematics. By the intervention teachers were exposed to the inclusion of applications in teaching mathematics, and their attitudes towards teaching applications of mathematics improved and their level of confidence to teach applications increased significantly (increased from 7 to 9 on a scale from 1 to 10). That means, the intervention helped the teachers to teach the applications of mathematics successfully and with self-confidence. Furthermore, despite the

* The authors equally contribute to the development of this paper.

¹ Babes-Bolyai University (Romania) & Alzhras School-Arraba (Israel). E-mail: abedallh_asley@yahoo.com

² Babes-Bolyai University (Romania).

* Corresponding author: iuliana.marchis@ubbcluj.ro



difficulties and the obstacles in teaching applications of mathematics in other disciplines, teachers liked to teach the applications of mathematics and were satisfied with the results and the change among the students. They reported that they would implement the teaching applications of mathematics in other disciplines in all classes that they teach and would recommend it to their fellow teachers.

Key Words: applications of mathematics, attitudes towards teaching mathematics, mathematics teachers

1. Introduction

In the literature of teaching mathematics, many articles have investigated the importance of teachers' and students' attitudes towards teaching mathematics and especially teachers' attitudes and the effect of these attitudes on students and teaching mathematics in general (Relich & Way, 1994; Skemp, 1976; Tuimavana & Datt, 2017).

Teachers' positive attitudes not only directly have a positive effect of learning mathematics among students and among their attitudes towards mathematics (Maria, 1992; Karp, 1991), but also influence teachers' teaching. For example, teachers with positive attitudes towards teaching mathematics use methods that are attractive and interesting to students, which causes positive attitudes of the students towards learning mathematics. This study shows the opposite: teachers who use attractive teaching methods, in this case "teaching applications of mathematics in other disciplines" will have positive attitudes towards teaching mathematics.

In this regard, the present study aims to find out the effect of teaching applications of mathematics in other disciplines on teachers' attitudes towards teaching mathematics. Teachers' attitude is studied by structured interviews before, during, and after an intervention with teaching applications of mathematics in high school mathematics classes.

The hypothesis of the study is that the intervention "teaching applications of mathematics in other disciplines" has a positive effect on teachers' attitudes towards teaching mathematics.

2. Literature review

The effects of teachers' positive attitude towards teaching mathematics

Teachers' attitudes towards teaching mathematics are very important and play a major role in teaching mathematics and in teaching in general. The studies that researched this subject showed the great and the wide influence of

the teachers' attitudes on teaching mathematics among students, on the attitudes of the students towards learning mathematics, on the successes of the students in mathematics, on the teaching methods of the teachers, and on the daily practice in the classroom (Maria, 1992; Skemp, 1976; Wilkins, 2002).

In the following several number of researches are presented that dealt with these issues and with teaching applications of mathematics in other disciplines and the interaction between them. Regarding to teachers' attitudes towards teaching mathematics, the studies of Maria (1992) and Tuimavana and Datt (2017) showed that there is positive effect between the attitudes of teachers towards teaching mathematics and the attitudes of students towards learning mathematics, which means: positive attitudes of the teachers towards teaching mathematics lead to positive attitudes of the students towards learning mathematics. Like this result, studies showed that negative attitudes of the teachers towards teaching mathematics have a negative effect on the students and create negative attitudes towards learning mathematics and cause a passive learner (Baturo & Nason, 1996). We can conclude that there is a big effect of the teachers' attitudes towards teaching mathematics among students' attitudes towards mathematics and at the same time there is an obvious effect of students' attitudes towards mathematics on students' success in mathematics. Many studies have shown that people with positive attitudes toward mathematics do better and are more successful than people with negative attitudes (Bayturan, 2004, Reyes, 1984; Ma, 1997).

Thus, the most important effects of teachers' attitudes towards teaching mathematics are on the students' successes in mathematics.

Therefore, in our opinion, there should be training for mathematics teachers on this subject and to make sure that the attitudes of teachers towards teaching mathematics must be positive in order to boost the students' attitudes and their achievements in mathematics.

In addition, many articles have investigated the effect of teachers' attitudes towards teaching mathematics among teaching methods and the procedure of the mathematics lessons and the daily practice of the mathematics class. Teachers' attitudes influence the teacher's methods and strategies. The result of teachers' positive attitudes is the use of methods and strategies that help students improve their understanding of mathematics (Amato, 2004).

Teaching applications of mathematics in other disciplines

Although there are not many studies in the literature of teaching applications of mathematics in other disciplines, the studies that dealt with this topic proved the importance and the benefits of it among both students and

teachers. So teaching applications of mathematics allows the student to see the importance of mathematics in everyday life, sees the beauty of mathematics, the connection of mathematics to the various fields of science, helps the students to understand and visualize mathematics, increases the student's motivation to learn, to love and enjoy learning mathematics, also causes to change students' attitudes towards mathematics for better and finally improves the student's achievements (Asli & Zsoldos-Marchis, 2021).

Several articles showed positive effects and the benefits of teaching applications of mathematics in other disciplines on students and teachers' attitudes toward teaching mathematics. For example, Yildirim and Sidekli, (2018) showed that applications of mathematics in STEM disciplines had a positive effect on mathematical literacy developed higher-order thinking skills in pupils and students as well. These applications also significantly influence students' attitudes towards mathematics studies, which led to an increase in academic motivation and an increase in the percentage of students with academic success.

In addition, teaching applications of mathematics enhances the learning atmosphere in math classes and turns a routine atmosphere into an active one for both teachers and the students as well as students' attitudes towards teaching mathematics have changed for the better and this led to a significant improvement in student achievement (Asli & Zsoldos-Marchis, 2022).

As we mentioned above, several articles and studies dealt with teachers' attitudes towards teaching mathematics and the importance of teaching applications of mathematics in other disciplines, but none of them dealt with the relation between teachers' attitudes and teaching applications of mathematics. This study is new in the field because it examines the effect of a new factor "teaching applications of mathematics in other disciplines" on teachers' attitudes towards teaching mathematics.

It is expected that new teaching methods and learning strategies that not all teachers are aware of and use such as "teaching applications of mathematics in other disciplines" will change teachers' attitudes towards teaching mathematics in a positive way, which is reflected positively on the students as well. This idea is consistent with the model of teacher professional of Clarke and Hollingsworth (2002) which is based on the fact that a change in one field is related to a change in another field. In the case of the current study, a change in teaching methods "teaching applications of mathematics in other disciplines" brings a positive change in the teachers' attitudes towards teaching mathematics. Clarke and Hollingsworth add that teachers must undergo professional growth that incorporates key features of contemporary learning theory. That is, the teachers must undergo professional development in order

to adapt themselves to the changes taking place and to the reality that changes every day. Furthermore, Guskey (1986) stated that significant changes in beliefs and attitudes are expected to occur only after significant changes in teaching outcomes. That means a change in the teaching results is related to a change in the teachers' beliefs and attitudes.

3. Methodology

3.1. Aim of the research

The aim of this research is to study the effect of the intervention with teaching applications of mathematics on teachers' attitudes towards teaching applications of mathematics.

3.2. Research instrument

The research instruments in this study are interview guides.

The first interview includes 16 questions about teachers' attitudes towards teaching mathematics and teaching applications of mathematics. It was applied before the intervention to teachers in both experimental and control groups.

The second and third interviews are similar, and they include 5 questions about teaching applications of mathematics. These interviews were applied only to the teachers in the experimental group and took place during and after the intervention.

3.3. Participants

The study involved four teachers and four classes from an Israeli high school. The name of the teachers will be abbreviated in the following with R, E, K and Re, where the acronym are initials of the following names: "R" =Reem, "E"= Eatedal, "K" = Kholod, "Re"= Reman. There are two 11th grade and two 12th grade participating classes. Each class is divided into two groups which are taught by different teachers at the same time (this is common practice for teaching mathematics in high school in Israel). Thus, one of the groups of each class was selected for the experimental group, the other one for the control group.

Regarding the level of education of the teachers, the four teachers have bachelor's degrees, all of them teach 11th and 12th grades and prepare the students for the matriculation exams in Israel.

Table 1 below contains the age and seniority in teaching of the teachers participating in the research.

Table 1. Data of age and seniority in teaching of the teachers participating in the research.

Teachers` name	Age	Seniority in teaching
“R”: Reem	36	13
“E”: Eatedal	28	6
“K”: Kholod	46	23
“Re”: Reman	35	10
Average	36.25	13

It is important to note that the youngest teachers are in the experimental group and the oldest in the control group for reasons of motivation and readiness for change and full cooperation with the research.

The control group included two teachers and 51 students, 25 students from grades 11-1 and 11-2 and 26 students from grades 12-1 and 12-2.

The experimental group included two teachers and 50 students, 25 students from grades 11-1 and 11-2 and 25 students from grades 12-1 and 12-2.

Each class is taught by two teachers at the same time and in fact each teacher from the studied teachers teaches two groups. The division of classes and teachers is presented in Table 2 .

Table 2. The division of participants classes and teachers in the research.

Teacher	Class	Group type
R	11-1 first half	Control
E	11-1 second half	Experimental
K	11-2 first half	Control
E	11-2 second half	Experimental
R	12-1 first half	Control
Re	12-1 second half	Experimental
K	12-2 first half	Control
Re	12-2 second half	Experimental

3.4. Data Analysis

The data obtained with the interviews before the intervention were analyzed identifying categories and themes (Shkedi, 2007). In the case of the teachers who participated in the intervention, their answers at the three interviews (before, during, and after intervention) were presented as case studies.

3.5. Intervention

The material studied during the intervention was “differential and integral calculus”, in particular, maximum and minimum problems. The same subjects were taught in both groups (control and experimental) and in both 11th and 12th grades. The 11th and 12th grades studied minimum and maximum problems for different types of functions: 11th grades for polynomial, rational, and root functions, and 12th grades for logarithmic, trigonometric, exponential, and power functions. In the experimental group also applications in other disciplines such as physics, construction, and economics of minimum-maximum problems were included. The intervention plan given to teachers contained the proposed examples of applications of mathematics in other disciplines for the subject taught. The plan also recommended the use of active teaching methods.

4. Results

4.1. The findings of the pre-intervention interviews

The findings of the interviews with the teachers in the two experimental and control groups before the intervention showed that *mathematics is an important subject* and is considered the basic subject of the other subjects and should be devoted more time and resources because mathematics is important for students for their studies and in everyday life as well as in future academic studies.

R: “Mathematics is considered a cornerstone of many areas and professions in our lives. We use mathematics a lot and it is the basis for many fields and disciplines [...]. Mathematics develops and strengthens our thinking and expands our horizons to other areas and disciplines.

Re: “It is important because we use and apply mathematics in everyday life [...].

It is a subject which develops students’ cognitive abilities, such as logical thinking, which is important in studying other subjects.

E- “Mathematics is one of the major and important subjects that is taught in the education system. Mathematical thinking imparts abilities such as problem identification, reasoning, and the use of solving aids, so mathematics allows student to think and solve problems and helps him in all sorts of areas of daily life”.

The interviewed teachers reported also *difficulties and obstacles in teaching mathematics*. Some of the difficulties are related to students such as their difficulties in understanding mathematics and solving mathematical problems, their lack of motivation for learning.

E: "Teaching math is not an easy task. One of the difficulties in teaching mathematics is the lack of motivation for students to learn. Most students see that mathematics is a difficult and irrelevant profession. Another obstacle is that mathematics is not intuitively connected to the student's emotional world. And for many students, math is a dry and difficult subject".

Other difficulties are related to financial, and time constraints.

K: "[...] lack of equipment and materials for illustration, time pressure and exams [...]."

As regarding the topic of the intervention, teaching applications of mathematics in other disciplines, one teacher reported that she occasionally teaches some applications, two rarely show applications, and one teacher never teaches applications. They teach applications in physics, economics, construction, and everyday life.

E: "Yes, I teach applications of mathematics in other disciplines, but not much, it depends on the time and topic being studied, if I am teaching a topic that can be applied in disciplines that I know, then yes I am teaching."

All the teachers see a difference between lessons with and without applications of mathematics. *Teaching applications of mathematics in other disciplines has many benefits*: students will become more interested in learning mathematics (stated by teachers R, K, Re, E) because they see the importance of mathematics (R, K) and its connection with everyday life (R). Because of the increased utility perception of mathematics, mathematics becomes more attractive (R), students' motivation for learning increase (K, E) and they understand mathematical notions deeper (Re, E). This leads to a more successful learning of mathematics (Re).

Re: "[...] By the application of mathematics in other disciplines and in daily life, the student feels the importance of mathematics, sees its beauty, see that mathematics is interesting [...]"

Despite the high importance of teaching applications of mathematics, teachers face *difficulties and obstacles* related to the educational system, the pressure of the matriculation exam (R, K, Re, E). Teachers feel the time pressure for finalizing the study material before this exam as the study material is huge.

Thus, there is lack of time for including applications in the lessons (R, K, Re, E). Another important difficulty is teachers' and students' lack of knowledge in the field of the applications (R, K, Re, E).

E: "It is difficult to teach mathematics applications in other disciplines when the discipline is unknown to the student or teacher."

Another difficulty is lack of necessary equipment (R, K). Presenting applications of mathematics needs more preparation time from the teacher (R).

R: "[..] Teaching applications of mathematics requires equipment and tools (money) and requires a lot of effort from the teachers in preparing appropriate lessons."

As regarding *teachers' confident in teaching applications of mathematics*, all the teachers reported that they can teach applications of mathematics in other disciplines at a medium to good level, but there are disciplines that are difficult for them and they are not good enough to teach applications of mathematics in them, and they need to prepare more and consult with teachers teaching those disciplines. Three teachers mentioned that they are familiar with applications in Physics.

Re: "I can moderately apply mathematics in other disciplines and especially in physics and in daily life but when it comes to mathematical applications in economics for example, I have to refresh the material and maybe also to learn new topics".

4.2. Case studies of the teachers participating in the intervention

4.2.1. The case of Re

Re loves mathematics and teaching mathematics, because mathematics is important as it can be used and applied in everyday life. She mentioned the following difficulties when teaching mathematics: "the heterogeneity of the study group, the perception among students that the subject is difficult, frightening, and frustrating, and the lack of motivation of the students". *Re* considered that her strength in teaching mathematics is "developing the inclusion capacity of struggling students and addressing outstanding students; and providing many opportunities for success".

Re considered teaching applications of mathematics important even before the intervention, because “student feels the importance of mathematics, sees its beauty, see that mathematics is more interesting”. Re taught occasionally applications of mathematics even before the intervention.

“I show to the students how mathematics helps them in other disciplines and explains the importance of mathematics as in physics and daily life, as in the field of construction [...] or bank.”

Her confidence in teaching applications of mathematics increased from the pre-intervention interview to the post-intervention interview. She pointed out the importance of the knowledge from disciplines in which mathematics is applied. In her opinion the teacher should have control over the other disciplines also in order to be able to explain the application of the mathematical knowledge in those disciplines. It is also interesting to compare Re’s answers related with her confidence of teaching applications of mathematics given at the three interviews: pre-intervention, during the intervention, and post-intervention. Her opinion didn’t change, but the answers become more and more detailed, the participation in the research as teacher in the experimental class helped her with self-evaluation of her competencies and a deeper understanding of the knowledge required for other disciplines. Her answer at the post-intervention interview is the following:

“It is important for me to have full knowledge and control over the study topics that I teach in class. When I teach applications of mathematics in other disciplines, it is important for me to have full knowledge and full control of these other disciplines as well in order to be a machine and to teach well and I will be confident in the material in which I apply mathematics. But I have not mastered all the other disciplines of science. For example, in order to teach applications of mathematics in the construction domain, I consulted and enlisted the help of a construction engineer. It will also be difficult for me, for example, to teach applications of mathematics in biology. It takes me time, effort and investment to prepare for such classes and it comes at the expense of the study material and the time according to the curriculum towards the matriculation exam.”

Regarding the benefits of teaching applications of mathematics, she considered even at the pre-intervention interview that students’ interest and motivation for learning would increase. Her opinion changed into better with the intervention, at the post-intervention interview she mentioned the following benefits:

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“Great interest of the students and raising motivation for learning among the students. Students love mathematics, study with pleasure and fun, students connect math to everyday life and other disciplines of science and finally I see a significant improvement in student achievement”.

Students in Re’s class received very well the learning of applications of mathematics:

“The students are interested, happy to learn applications of mathematics. For example, students who have difficulty in mathematics, connect very much to the lessons. In particular, when I apply the subject of trigonometry to everyday life, like the subject of construction, students are more interested and see that it matters what they study. as well as understanding why we need math in everyday life. In addition, the motivation of the students increases, they enjoy learning and there is a noticeable improvement in the achievements and grades of the students”.

As regards the obstacles of teaching applications of mathematics, seems, that the time constraint is the most important one, it is mentioned by Re in all three interviews. At the pre-intervention interview she considered important obstacles the “difficulty in adapting relevant applications to the students according to their level of learning” and “insufficient training and knowledge of teachers in other disciplines to apply mathematics in these fields”. It is interesting, that after starting the experiment these two obstacles are not mentioned in the other two interviews. But the worries related with time and curriculum containers are more detailed, the worry not to properly prepare students to matriculation exam seems to be the main obstacle in teaching applications of mathematics:

“The main problem is lack of time and worry about not providing the material, so we have an annual curriculum and need to suffice the material for the matriculation exam at the end of the year, i.e., there is not enough time to teach applications of mathematics in other disciplines.

In the post-intervention interview an additional obstacle is given by Re: students’ knowledge in the disciplines in which the application of mathematics is presented. This shows that students had difficulties regarding some of the applications presented during intervention. These difficulties are presented by Re in the following way:

“There are many difficulties for the students in teaching applications of mathematics, like difficulty in transitioning from verbal language to mathematical language and especially in word problems, as well as difficulty in understanding the other disciplines in which we need to apply mathematics like physics for example. In addition, if the teacher gives the students a task or self-task, they have difficulty connecting mathematics to other disciplines or have difficulty applying mathematics to other disciplines on their own, but when the teacher does this in class they understand and enjoy”.

4.2.2. The case of E

E loves mathematics because it “is interesting, challenging, and fascinating”. In her view, “mathematics is important for understanding the world, math teaches us to think, it gives tools for solving problems in daily life”. She also likes teaching mathematics because she considers it fun and challenging. It is not easy to teach mathematics because of the lack of motivation of the students and their difficulties in understanding mathematics. She is a teacher who is preoccupied about students’ success in mathematics, trying to show the students the utility of mathematics in everyday life and its beauty. E also tries to encourage and motivate struggling students by giving them tasks with progressively increasing difficulty in order to give them the opportunity to feel the success. She considers the personal relationship with the students important.

“I always make sure that my personal relationship with the students is good. I love my students and give them the maximum possible. I believe that every student can succeed. I always encourage them and give them positive reinforcements.”

E considered teaching application of mathematics important even before the intervention. The benefits of teaching applications mentioned by E didn’t change from pre-intervention interview to post-intervention interview, but after the intervention the description of the benefits is more convincing, it is based on the observations during the intervention. The most important benefit is that mathematics becomes more interesting for students. When teaching applications of mathematics “students are more interested and listening in the class, they enjoy learning and learn with more motivation”, because they see its connection with daily life.

“Before I teach applications of mathematics in other disciplines, there were many students who were not interested in mathematics because they thought that mathematics is not related to everyday life and mathematics has no

connection to the other disciplines of science. But after teaching applications of mathematics in the other disciplines and teaching applications in the daily life of the student, this has changed. [...] Students' interest and motivation for learning and their enjoyment of learning increased, and they had better achievements".

The given difficulties of teaching applications of mathematics remain the same on the three interviews: lack of knowledge in the other disciplines, lack of time and the pressure of the matriculation exam. In the post-intervention interview E mentioned that "it is difficult to rely on students to prepare assignments or to study alone applications of mathematics in other disciplines". This shows that the experiment helped E to know better students' knowledge and competencies in the disciplines where applications were taught.

E's confidence for teaching application of mathematics has increased from 7 to 9 on a scale from 1 to 10. She said, that before the intervention she "had mediocre information and ability", but after teaching applications of mathematics in other disciplines and experiencing it, she "already see herself mastering very well and can successfully teach applications of mathematics in other disciplines" because she has already gained some experience.

Conclusions

The main conclusion that can be drawn is that teaching applications of mathematics in other disciplines has a positive effect on teachers.

Before the intervention the teachers used to teach according to the standard methods for the matriculation exams and they were constantly under pressure in order to finish the material and to get the students ready for the exams. Most of the teachers didn't teach applications of mathematics and those who did, they taught applications of mathematics infrequently and not sequentially. Besides, the teachers were not qualified enough to teach applications of mathematics and were not aware of the advantages of teaching applications of mathematics on students and on their own professional development.

However, after the intervention an important change was noticed in teachers' attitudes and teaching. The teachers became well qualified and were able to teach applications of mathematics since they were exposed to the strategy of "teaching applications of mathematics in other disciplines". Indeed, they acquired knowledge and became skilled and competent in teaching applications of mathematics. Furthermore, their level of confidence to teach applications increased significantly (increased from 7 to 9 on a scale from 1 to 10).

The results confirm that the intervention helped the teachers to teach the applications of mathematics with great success and total self-confidence. Participating teachers reported that the intervention had a great effect on the students as well: The students showed a great interest and a desire to learn mathematics.

Overall, the results demonstrate the improvement of the teachers' attitude towards teaching applications of mathematics. Finally, despite the difficulties and the obstacles in teaching applications of mathematics in other disciplines, the teachers reported that they would adopt the method "teaching applications mathematics in other disciplines" in all the classes that they teach and would recommend the method to their fellow teachers.

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APPENDIX

Pre-intervention interview questions

- Q1- Tell me about yourself, about your academic and professional background.*
- Q2-Tell me about the school and the classes that you teach.*
- Q3- What do you think about the profession of teaching mathematics (your opinion)?*
- Q4-Tell me why it is important to teach math?*
- Q5-What are the obstacles and difficulties in teaching mathematics?*
- Q6-What are the benefits of teaching mathematics?*
- Q7-What are the threats you fear in teaching math?*
- Q8-How can you improve your mathematics teaching?*
- Q9-Mathematics is a difficult subject that many students face. How do you deal with this problem? What techniques and strategies do you use with struggling students?*
- Q10-How do you make teaching mathematics an attractive and enjoyable Subject?*
- Q11-What are your strengths / weaknesses as a mathematics teacher?*
- Q12- What do you think about teaching applications of mathematics in other disciplines? Is it important and helpful or not? Explain your answer!*
- Q13-Do you teach applications of mathematics in other disciplines?
If Yes, in which disciplines?
and if No, why?*
- Q14-In your opinion is there a difference between lessons that you teach applications of mathematics in other disciplines and lessons that you don't teach applications of mathematics in other disciplines? --- In your opinion what are the differences?*
- Q15-What are the benefits and what are the obstacles of teaching applications of mathematics in other disciplines?*
- Q16-How confident are you in your capability for successfully teaching applications of mathematics?*

Interview questions during and after intervention

- Q1: What benefits do you observe when teaching applications of mathematics?*
- Q2: What difficulties do you face when teaching applications of mathematics?*
- Q3: How do students receive applications of mathematics?*
- Q4: What difficulties do students face when teaching applications of mathematics?*
- Q5: How confident are you in your capability for successfully teaching applications of mathematics? (on a scale from 1 to 10).*