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ISRAELI MATH TEACHERS' VIEW ON INTEGRATION OF STEM MODULES IN MATHEMATICS STUDIES AS A MOTIVATOR IN 9TH GRADE

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Abstract. In recent years, one of the main problems in learning mathematics is the motivation of students. It is important to use the possibilities of modern technologies and the availability of a STEM environment for the development and implementation of learning resources that will increase students' motivation to study science and mathematics in depth. This report presents the results of a study conducted to evaluate the incorporation of problem-based learning (PBL) learning modules in motivating students to learn mathematics. The study was conducted in Israel with 9th grade students and their teachers. As part of our research, we developed a unique intervention program, tested its effects on the defined target groups, and attempted to determine the impact of the program on subgroups of students. The impact of the program was tested using pre- and post-program questionnaires checking the ability feeling, the perception of relevance, and the motivation using the MMQ /Mathematics Motivation Questionnaire/ and in-depth interviews with students and teachers. One of the aspects of the study examined teachers' attitudes toward integrating the modules of STEM into the 9th grade mathematics curriculum. About 50% of teachers in the study, see major benefits for students in integrating STEM modules into mathematics instruction, but only about 25% see benefits for the teachers themselves. 90% of the teachers in the study, see certain challenges in combining these units, both for the teachers themselves and for the students.

Keywords: STEM; teachers; mathematics; motivation

Background

The State of Israel is internationally recognized as a "start-up nation" (Drori, Netivi 2013), a country where the number of successful start-up companies relative to the size of the population is significantly higher than in other countries

in the world, and second only to Silicon Valley in California, USA, in the world. However, the percentage of the population working in STEM professions in Israel is only about 9%. Landman (2017) found that the main bottleneck in STEM studies in general and in high level mathematics, especially in the state of Israel, is in junior high school and in the transition from junior high school to high school.

In recent years, the motivation of students in Israel to choose to study mathematics at a high level has decreased, mainly because they do not understand the benefits and usefulness of this study.

Students' performance in the PISA tests is not in the top group, but only in the third group[1]. The PISA studies conducted at age 15 are considered the most successful predictors of "success in life." These studies examine, among other things, literacy skills and the use of mathematical reasoning to solve complex realistic problems. Analysis of the studies from PISA shows that there is a correlation between curricula that combine math skills and multidisciplinary problem solving and success on the tests, as opposed to primarily disciplinary learning that does not lead to success on the tasks included in these studies.

Math skills and STEM go hand in hand in middle school (English 2016; Leung 2020). Expanding the practice of these subjects in junior high school mathematics classes demonstrates the relevance of mathematics to real, everyday life, demonstrates the practice of STEM subjects in the world of work and careers, develops problem-solving skills, increases teacher satisfaction with teaching the subject, and, most importantly, allows more students to choose pathways to learn STEM and high-level mathematics in high school. This can pave their way into academia and the workforce.

Many studies show that the transition from junior high school to high school is a critical transition point for students. One dramatic figure in this transition is the dramatic decline in the number of students taking high-level math, which also corresponds to the number of students choosing science subjects in high school. The causes of this dramatic decline have been studied, and it has been determined that the main reasons are student choice and the conscious and unconscious decisions of teachers, such as:

1. What are we doing with these professions in general? Why is it important?
2. Why should I study difficult subjects and not the easier ones? Can I do it?
3. Why should I invest my time in studies and not in leisure culture? What do I get out of it?
4. Overt and covert, conscious and unconscious teachers who, out of distrust in students' abilities, steer them into non-scientific fields.
5. Overt and covert gender stigmas that steer female students into non-science careers.

That is, three main factors influence students' decisions to study these subjects at the secondary level: a sense of the subject's relevance, a sense of self-efficacy, and motivation to invest in learning.

In Bulgaria, there is experience in promoting STEM educational resources, for example, through IMI-BAS as part of the international network STEMPD – Net of leading European centers for professional development of STEM teachers (Chehlarova, Maas, Sendova, Kenderov 2018) and as Scientix National Contact Points, coordinated by European Schoolnet (Chehlarova, Ivanova, Kenderov, Sendova 2021), and with the creation of new resources, focusing on the research approach to mathematics learning. Geometric figures and construction tasks are used, for example, in the study and restoration of artifacts (Chehlarova 2021), in the application of technologies such as augmented and virtual reality, holographic images (Chehlarova & Chehlarova 2020), and so on. Geometric figures are useful in the use of dynamic software for solving tasks related to games, for example, billiards (Chehlarova 2022), dominoes with figures with an axis of symmetry (Chehlarova 2021). Applied tasks, for the solution of which auxiliary files with geometric figures are provided, are available in the online competition "VIVA Mathematics with Computer" (Kenderov, Chehlarova & Gachev 2021).

The pedagogical idea and stem modules

The basis of the study is the proposition that if we get students and teachers to engage in inclusive STEM subjects relevant to their everyday realities in 9th grade, we can influence their attitudes toward these subjects, their importance, their sense of competence, and their motivation, and thus positively influence students' choices of math and science majors.

We conducted applied research in this area by combining learning of realistic topics relevant to students' daily lives in 9th grade based on STEM knowledge and skills with problem-based learning and studying the effects of combined learning and engagement with these topics on students' and teachers' perceptions and choices of majors at the beginning of 10th grade.

We have selected topics from students' daily lives that can, in principle, be analyzed using the mathematical tools and skills of ninth grade students. The topics of the integrative learning modules based on STEM (literacy, science, technology, and math) that we have written and are working on for ninth graders and their teachers are:

1. SOLAR ENERGY: The need, the technical solution, and the economic considerations
2. FLAT SCREEN TVS: How do they work? What are colors and 4K, and what does math look like on the screen?
3. "IRON DOME" System: How do you intercept an enemy missile?
4. GPS SYSTEM: How does my phone know where I am, and what is the shortcut to the nearest pizzeria?
5. CAR SAFETY SYSTEMS: How can the camera measure the distance to the car ahead?

Pedagogical STEM module structure

1. Familiarity with the problem/need using information sources. For example, in the solar energy module: global warming and the desire to reduce fossil fuel use.

2. Familiarity with relevant scientific field, with hands-on experience in lab or simulation. For example, in the solar energy module: experimenting with a laboratory solar cell and figuring out the factors that affect the strength of the electricity generated.

3. Practical considerations in designing the solution, including quantitative, geometric, and economic calculations, etc. For example, in the case of the solar energy system: calculating the amount of electricity generated depending on the geometry of the roof and the solar radiation, calculating the costs and the economic return.

4. Summarizing task and presentation of a product in which the acquired knowledge is presented, e.g., product planning, presentation of the topic, questions for further investigation, etc. For example, in the solar energy module, students planned the sizing of the solar system for a typical house and presented the economic viability of different roofs.

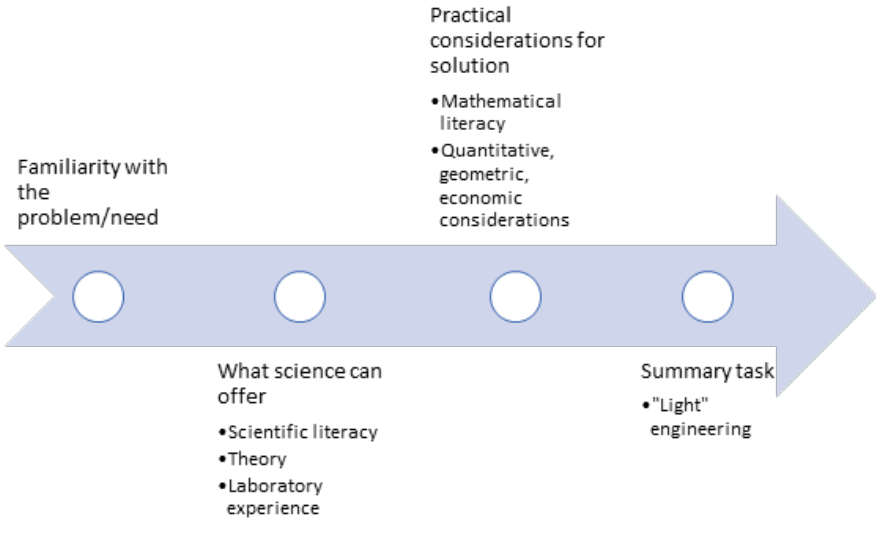

Figure 1. Schematic pedagogical structure

In developing these modules, emphasis was placed on the following features:

1. Illustrate the transition process from science to technology to solve key problems, with literacy and mathematics as the "language" of the process (Falloon, Hatzigianni, Bower, Forbes & Stevenson 2020; Julia & Antoli 2019).

2. Hands-on experiences in the lab or through simulation of the science and

technology problems related to the module of study.

3. Integration of science, math, and other subjects from the 9th grade curriculum.

4. Guided learning in small groups using a PBL (Problem Based Learning) approach.

5. A combination of existing disciplinary knowledge, existing general knowledge, and self-directed learning skills

6. Tasks that allow each student to complete them according to their level of proficiency, with the goal of providing students with successful experiences completing the tasks.

7. A "summary literacy task" that connects the acquired science and math knowledge to the main problem addressed in the module.

Each module is planned for 3 – 4 lessons period. During the learning, students are divided into work groups of 2 – 3 students and complete the tasks while science, math, and language teachers are nearby to help and guide as needed.

The research also addressed how to deal with teachers' difficulties and objections, which have been found to be one of the factors hindering the implementation of STEM in schools. Teachers whose educational training and professional development is uni-disciplinary and who are accustomed to being the source of knowledge in the classroom find it difficult to successfully adopt and apply multidisciplinary and interdisciplinary approaches and PBL techniques. This difficulty is exacerbated when teachers are expected to lead student learning in subjects not traditionally included in the curriculum with which teachers are familiar. To this end, we have trained teachers to participate in research, built a community of math and science teachers (Kelley et al. 2020), (Brand 2020) to discuss and support implementation and adaptation in classrooms, and closely guided them in this process.

An example of STEM module: SOLAR ENERGY: the need, the technical solution, and the economic considerations

Headlines

– Opening: understanding the need.

– Experimenting with a laboratory solar panel and identifying factors that affect the electricity output.

– Geometric planning of a solar system for the required output in different sun directions

– Home system planning.

– Calculation of economic viability.

A taste of the activity

Figures 2a and 2b can give us a taste of the activity, and the mathematical skills that should be used.

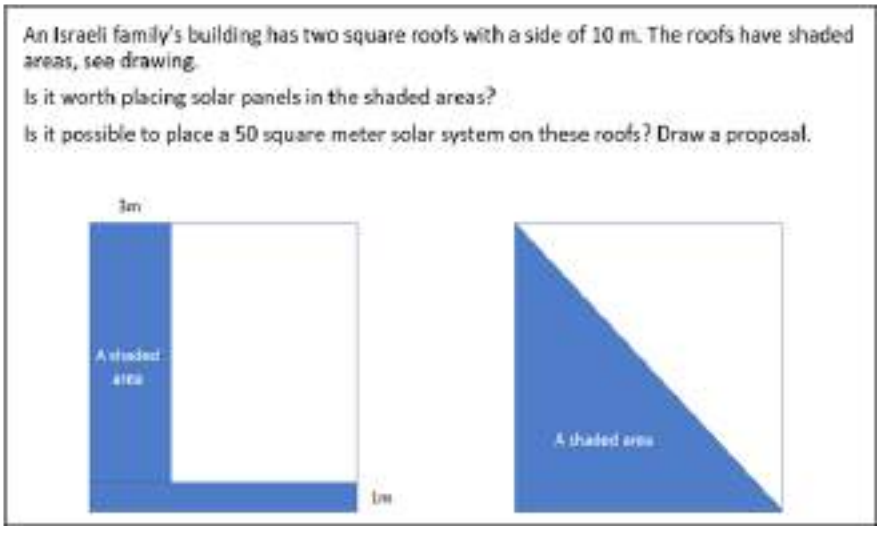

Figure 2a. Solar energy module: home system planning, geometrical considerations

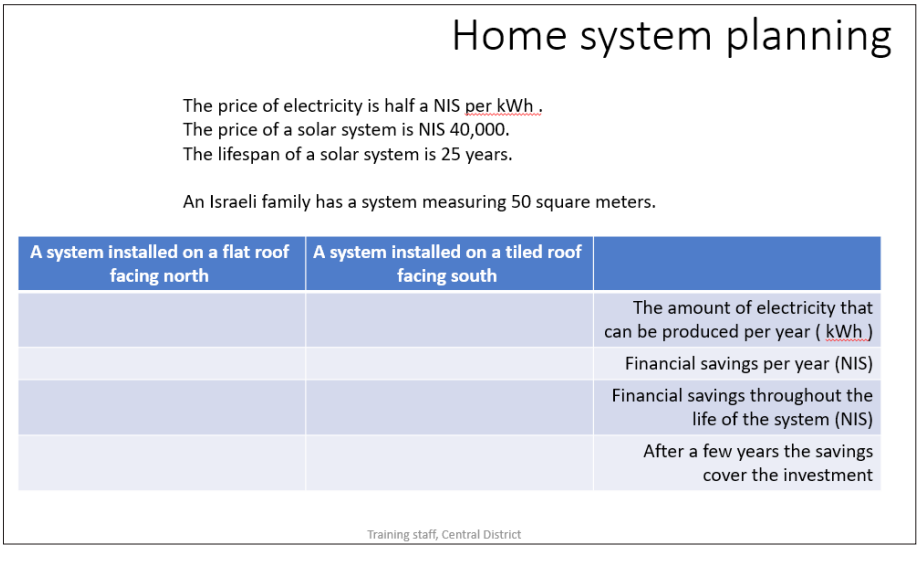

Figure 2b. Solar energy module: home system planning, economic considerations

Research area and time frame

The study was conducted in middle schools in the central district of the State of Israel in the 2022/2023 school year.

In the central district of the State of Israel, there are about 145 junior high schools with about 425 9th grades and about 17,000 students. We activated the intervention program in 6 schools (4% of the content). 20 teachers participated in the study.

The impact of the program was tested using pre- and post-program questionnaires checking the ability feeling, the perception of relevance, and the motivation using the MMQ /Mathematics Motivation Questionnaire/ (Fiorella et al. 2021) and in-depth interviews with students and teachers.

The process with teachers

After principals approved implementation of the program in their schools and identified math and science teachers to participate in the program, a community of teachers was established. The community met four times during the program, during which we discussed the topic of STEM in general and its appropriateness for 9th grade, and teachers also experienced the modules so they could guide their students in implementing it.

The program was facilitated by a team of math and science instructors from the Ministry of Education, who were also partners in creating and revising some of the program's instructional modules.

November 2022: First community meeting of the mathematics and science teachers of the classes to participate in the program, where the concept of STEM, the rationale for the program, the objectives, and the way of working in the field were presented. At this meeting, the teachers also experienced the first module. The teachers were instructed to hand out the opening questionnaire to the students and introduce the program to them. The duration of the meeting was three hours.

After that, in November 2022, the students studied the first module in teamwork under the guidance of the teachers.

December 2022: Second community meeting, where we discussed the findings and lessons learned from the first round. In the second part of the meeting, teachers received the draft of the 2+3 modules, experimented with them, and made suggestions to improve them. At the end of this meeting, some of the teachers said that they now know what is done with math in "real life". Duration of the meeting: 3 hours. After that, in December 2022 and January 2023, the students studied the second and third modules in teamwork under the guidance of the teachers. The teachers received initial positive reactions from the students, and the teachers also discovered the unique added value of the program and began to give positive feedback to the program as well.

February 2023: Third community meeting, where we discussed the findings from the previous rounds and presented the STEM programs that exist in selected

education systems around the world. In the second part of the meeting, teachers received the draft of module 4, discussed it and made suggestions for its improvement. Duration of the meeting: 3 hours. After that, in February 2023, students studied the second and third modules in teamwork under the guidance of teachers.

March 2023: Fourth community meeting, where we discussed the findings from the previous rounds. Teachers then received the draft of module 5, the final module, experimented with it, and made suggestions to improve the module. In the second part of the meeting, we discussed the question of whether and how such a program could be included in the regular curriculum. Duration of the meeting: 3 hours. After that, in April and May 2023, the students studied the second and third modules in teamwork under the guidance of the teachers.

In June 2023, teachers completed the final questionnaire (Appendix A), and several in-depth interviews were conducted with teachers of the program.

Results

Twenty teachers participated in the program. At the end of the program, we asked them about the main benefits they saw in integrating STEM into the mathematics classroom, both for teachers and students.

Figures 3 and 4 show how the teachers perceived the benefits for the students and the teachers themselves.

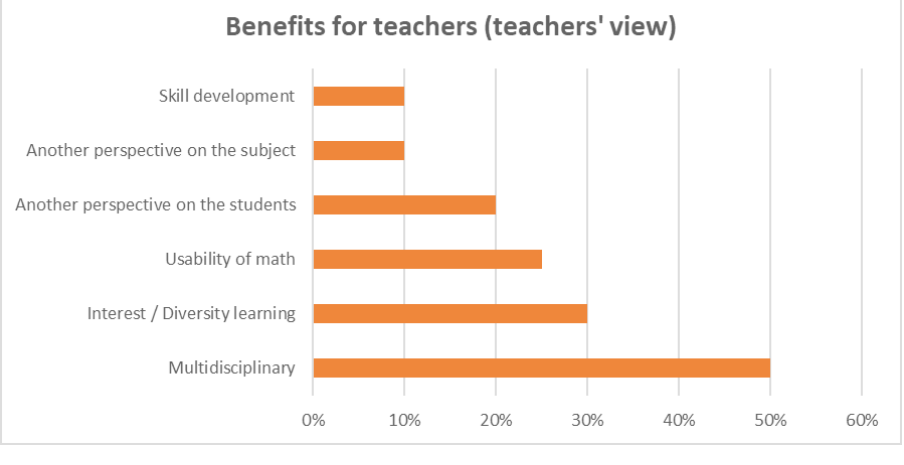

Figure 3. The percentage of teachers who see different benefits for teachers

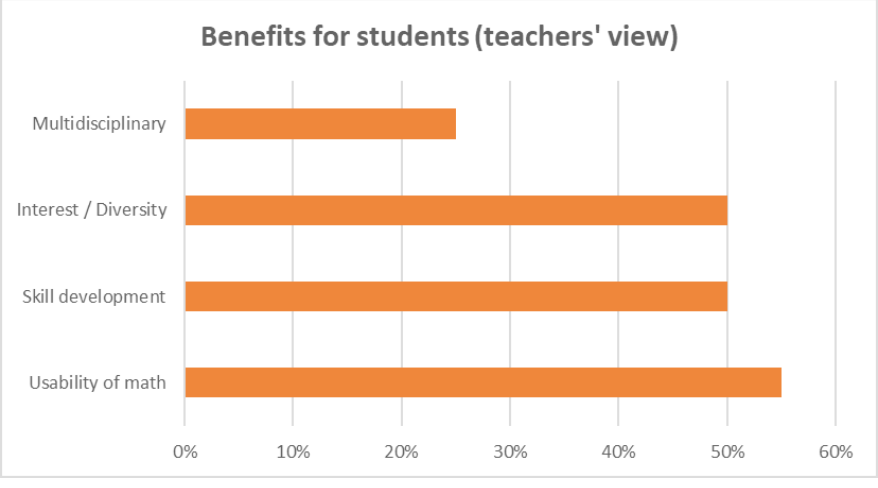

Figure 4. The percentage of teachers who see various benefits for students

Another question asked of teachers was about the challenges the program presents to teachers and students. The concentration of responses is shown in Tables 1 and 2.

Table 1. Possible challenges for teachers (teachers' view)

Challenge	**No.**	**%**
Organization and logistics	6	30%
Getting to know the material	4	20%
Time investment	4	20%
Adjustment for struggling students	4	20%
Innovation	2	10%
Canceling lessons	1	5%
Link to the study material	1	5%
Teachers' collaboration	1	5%
None	2	10%

Table 2. Possible challenges for students (teachers' view)

Challenge	**No.**	**%**
Teamwork	6	30%
Low level of knowledge	5	25%
Motivation	3	15%

Learning skills	3	15%
Literacy	2	10%
Integration in the learning sequence	1	5%
None	3	15%

From the data, about 50% of teachers see major benefits for students in integrating STEM modules into mathematics instruction, but only about 25% see benefits for the teachers themselves.

Teachers see certain challenges in combining these units, both for the teachers themselves and for the students.

The challenges for teachers are mainly in the deviation from the regular curriculum, in the organization, and in the need to collaborate with other teachers.

The challenges for the students are in the area of knowledge and skills.

Phrases from the teachers' interviews

1. What are the main benefits of STEM activities?

a. "An opportunity to get to know the students in an unusual activity. A more systemic point of view."

b. "Combining areas of thought, leaving the learning framework, applying mathematics in the areas of life, answering the question "why do we need this."

c. "Seeing the students in a different activity, combining subjects, multidisciplinary learning."

d. "Makes students access to topics from life in which mathematics is integrated and everything is so current and relevant."

e. "Deepening the study material, linking the material to life relevance, creating interest in the student."

f. "Developing research skills and cooperative learning."

g. "Independent learning of the children, under the same subject, in the study unit, learning is carried out while combining a number of studies subjects."

2. What are the main challenges in these activities?

a. "Students ask questions not necessarily from the teacher's field of knowledge."

b. "Need of openness, flexibility, organization and time."

c. "Coordination with other professional teachers."

d. "Encourage weak students to take part and not rely only on the strong ones."

e. "Mainly logistical, finding time to study these subjects, finding time to carry out the activities, causing interest among the students."

f. "I don't recognize anything special. Of course, it is necessary to adjust the level of the activity to the level of knowledge, otherwise there will be frustration."

g. "A slightly different way of thinking, once you get used to it, it becomes very easy."

h. "Nothing. We enjoyed a lot."

i. "Reading comprehension of part of the activity."

j. "Unfamiliar material for students. Difficulty for those who don't like to study with friends and alone."

k. "Combining different areas of knowledge contributes to experiential learning and getting out of the routine and also enriches their knowledge."

Conclusions and summary

The purpose of the study was to examine whether integrating STEM into ninth grade mathematics classes can increase students' motivation to study mathematics by strengthening their sense of the value and usefulness of the subject.

Teachers see great benefit in this program for students, and some of them see benefit for the teachers themselves but they are a little afraid of the challenges associated with this project.

Mathematics teachers are happy to integrate STEM units into the curriculum as a motivational tool, provided they receive support for it and there is appropriate organization in the school.

Appendix 1

Teachers' final interview

What are the main benefits of STEM activities for teachers? Please specify ___
_____
_____

What are the main challenges in these activities for teachers? Please specify.
_____
_____

What are the main benefits of STEM activities for students? Please specify ___
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_____

What are the main challenges in these activities for students? Please specify.
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_____

NOTES

1. OECD (2022). *Israel student performance (PISA 2022)*. Available from: https://gpseducation.oecd.org/countryprofile?Primarycountry=ISR&treshold=10&topic=PI

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