PBL effects on engineering education in junior high school robotics practice

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Abstract: - The practice of "meaningful learning" has become an inseparable part of the educational discourse. As a result, many schools have adopted the Project Based Learning approach (PBL), which represents different teaching methods. The PBL approach also changes the position of the teacher as a source of knowledge as well as teacher-student relationship. The integration of project-based learning (PBL) and its implementation in the teaching of the robotics profession in junior high schools, have created a new reality in which teachers who use project-based learning for teaching robotics come from diverse professional backgrounds, and in many cases, they are selected by the principle of the school. Therefore, we examine the teaching experience of teachers, who manage a project in a field of knowledge that is not their expertise. This study examined teachers' perceptions of their experience in teaching using the PBL approach. The study data was collected using structured questionnaires, which also included open-ended questions. These questionnaires were answered by teachers from different fields of knowledge: social studies, sciences and engineering. Each questionnaire included attitudes relating to the PBL teaching experience and the contribution of the PBL approach to both teachers and students. The findings show a high level of general satisfaction among the teachers and a sense of self-efficacy in teaching PBL. The findings additionally indicate that class tutors perceived the ecological contribution more than professional teachers, and professional teachers in the fields of human studies and sciences perceived it is more significant than engineering teachers. The following discussion presents the implications of teaching using the PBL approach as a pedagogical approach that indicates a change in the traditional role of teachers.

Key-Words: Project Based Learning (PBL), Project Based Teaching, Robotics, Meaningful Teaching

1 Introduction

The Constructivist Theory, which serves as a theoretical basis for this research, is a conceptual framework that helps to deal effectively with the search for knowledge construction, and many teachers and educators currently integrate it in their educational work as seen in [1]. The constructivist theory places the teacher and student as an integral part of the learning process. According to this theory, learning is an active process that involves both teacher and students, who together create meaning and reach insights as to the learning situation. The new knowledge is actively acquired by both teacher and student by connecting it to existing knowledge ([2]).

PBL is one form of pedagogy that attempts to implement the above-mentioned constructivist theory. This approach not only represents different teaching methods, it also fundamentally changes the objectives of traditional learning, as PBL emphasizes the process as knowledge and the process as a target and not only a means to reach a certain final product. The Horizon Report ([3]) elaborates the importance of such a change, indicating the growing need in developing study programs that are based on and incorporate the PBL approach.

Often, this approach is preferred for teaching STEM professions (STEM- Science, Technology, Engineering, and Mathematics). Despite of the broad consensus in literature, emphasizing its many advantages, many teachers focus on the difficulties

in applying this approach in relation to the limitations of the methods employed in regular schools ([4], [5], [6], [7]).

In the early 1990s, Papert ([8]) developed the original theory of "Constructionism" which merged the ideas of constructivism, while emphasizing the importance of choosing a project that relates to a subject that is of interest to the student, and through this project he or she will learn the other professions. He also showed that significant learning occurs when teachers and students construct together meaningful physical models to create products that they can share with others, such as friends or parents. In addition, Papert paid particular attention to the role of real-world experiences.

As mentioned, PBL is a learning approach that is organized around a project that involves a tangible product that motivates the activities of both the teacher and student. The learning process involves the completion of various complex tasks and defined schedules. When the project is completed, the students present their product to their close community, explain it, defend it and reflect on the learning process.

The teacher is required to incorporate key elements in the learning process. These elements include project management methods, time planning for tasks, reference to authentic problems derived from the contents learned, research of new concepts, learning that involves research and construction of knowledge, incorporating the knowledge learned in real-world actions, production and presentation of a tangible product.

The role of teachers who employ the PBL approach is significantly different than the traditional roles, which focus on the transfer of knowledge, a role that required teachers a high degree of knowledge in several fields, as well as management skills and the ability to impart the knowledge to their students ([9]).

From the teachers' point of view, PBL is a combination of innovative teaching and meaningful learning, which affects three aspects: personal, professional and ecological. All those engaged in PBL agree that it is a continuous process of development that takes place in constant interaction between the individual and the environment in which he functions ([10]).

The positioning of the teacher in a PBL environment is done in three different intertwined aspects as seen in Fig.1:

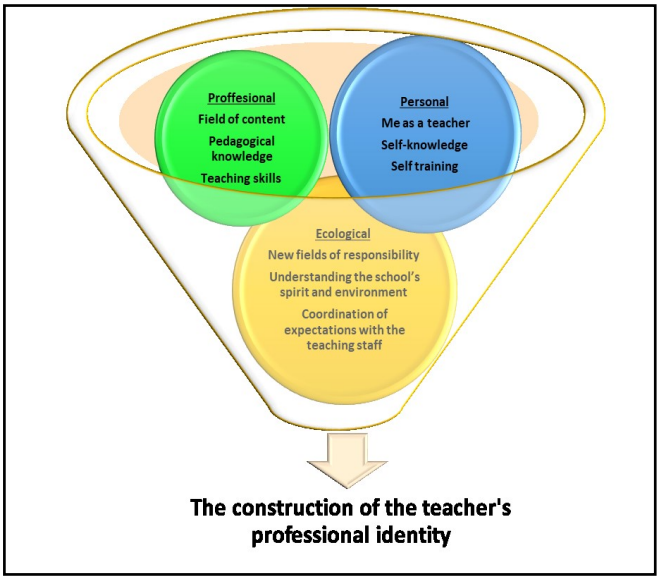

Fig.1: The teacher's professional identity construction

- **The personal aspect**: The topic of self-positioning is one of great importance to teachers. Hormuth ([11]) argues that understanding one's self is achieved and developed through social interaction. Hormuth defines the components of the self, that is, the environment and elements that provide social interaction, connect it and perpetuate it as the ecology of the self. The self is described as the internal organization of external behavioural roles. Self-perception is the interdependence in others, objects, and environments. As long as the individual's self-ecology is stable, the self-concept will also be stable, and it will strive for personal maintenance. Changes in self-positioning occur as a result of an imbalance in the ecology of the self. Such ecology leads to re-positioning in different ecological conditions, and to the reorganization of the self-ecology. In this study the change teachers undertake relates to the teaching method they employ. In other words, a teacher who engages in an innovative pedagogy and employs an innovative teaching method causes an imbalance in the social system, thus enabling a change of his or her self-positioning.
- **The Ecological aspect**: As noted above, teachers undergo a process of personal development in the context of the school. This process involves their adjustment to the school's culture and beliefs, or its

educational goals and proper professional practices, such as teacher performance, teacher-student relations, among others. In a school environment, where there are several learning cultures, there are written, and unwritten rules and teachers expect that these rules will be upheld. Hargreaves ([12]), points out that teachers who begin a project do not always recognize the written and unwritten laws of the key members in the new school. They usually discover them by surprise, or as a result of a problem that arises during their work. Each of the various subjects of study has learning traditions that the teachers and students are accustomed to. When a teacher employs new teaching methods, the other teachers and students do not always know how to deal with such change. In his paper he argues that most teachers do not interpret new methods as a challenge, but rather as a source of confusion. The employment of a new teaching method requires teachers and students to learn how to study according to the new conditions, a process that prefer to forego and return to existing and traditional methods. The difficulties mentioned above force the teacher, who begins a project, to rephrase the concept his or her concept of self. The environmental pressure to adapt to the new environment, however, causes many teachers to feel that the knowledge and skills they have acquired and employed in a satisfying manner during their initial training, do not always work in the school environment. Often such a process appears to be a process of adaptation to the teachers' environment ([13]). Teachers who start projects must learn, how to deal with the new responsibilities, how to act as project managers, how to direct their perceptions towards proper work methods and the reality of the school in which they operate and keep them in harmony with their own personality. This is especially true in situations where teachers do not receive the necessary support, which causes them to experience the initial stages of the project as a kind of acceptance ceremony rather than an important learning experience. This is despite the fact that the process of adapting to a new environment is inherently interactive ([14]).

- **The Professional aspect**: The professional knowledge and skills of the teacher who begins a project must develop in the following three dimensions:(1) Knowledge and pedagogic content. (2) Management skills. (3) Organizational skills. Kagan ([15]) suggests that the first years are inseparable from study and guidance. During this period, teachers tend to think of their inability to nurture and promote student learning as a lack of classroom management skills. Many teachers, who begin a new project, need to invest much time to learn the material. Even if they have extensive academic knowledge, they encounter unexpected problems in translating academic knowledge into school knowledge, and they must redesign their knowledge base. Shulman ([16]), related to the problem of developing teacher's knowledge. A close examination of the knowledge of teachers who have experience in teaching and leading projects, led him to the conclusion that they derive their knowledge from sources of knowledge identified as academic, pedagogical, knowledge of purposes and goals, students' knowledge, knowledge of educational content, and knowledge of definitions and administration. He suggested that these sources of understanding, which form the knowledge base of teacher’s pedagogical content, are the most important component. This knowledge enables the thinking process, the pedagogical action, and the practical analysis of the concept of knowledge and pedagogic content. A teacher who begins a project, sometimes lacks depth and breadth in the subjects, and in spite of all his or her initial training and pedagogical knowledge, the teacher does not have full understanding of the material, in the school and student level, and he lacks the knowledge and understanding of the many ways in which a certain topic can be taught. The study and improvement of this type of knowledge is possible only through action. For example, a teacher who strengthens his belief in his professional ability (personal component) may use the knowledge he acquired more efficiently (professional component) and strengthen his status in the classroom and in the school (ecological component).

The role of the teacher in meaningful learning, and especially in project-based learning, is fundamentally different from that of traditional learning. From the teacher's perspective, projects that are part of project-based learning are open-ended, and in the long run they are integrative. It is an investigation conducted in a joint framework with the students, and it is created or developed according to the students' contribution. The projects should be as authentic as possible, that is, they should include tangible goals, and relate to sources from the "real world" as presented in [4].

The teacher has a vital role in the learning process: he is responsible for creating an environment that enables opportunities to experience. He is also responsible for helping students understand how to learn. The teacher needs to consider and prepare himself for the different directions the students may follow, as well as where the students can search for information, and how they can best implement the new knowledge. The teacher has to conduct mini-lessons and conversations and choose reading materials or write schedules for the entire class ([17]).

It is important to remember that there are several ways to carry out projects. The teacher must approach the idea of projects, its context and its strengths, in an appropriate manner. The work on projects rarely involves lectures by the teacher to the entire class. Instead, the teacher goes between the different groups of students, asks questions, offers suggestions, and challenges their thinking. In the context of project-based learning, the teacher functions more as a mentor, a guide, a resource for the students, and, most importantly, as a long-term project manager.

Many studies such as [18] and [19], have examined the Project-Bases learning approach in comparison to traditional learning. These studies have indicated several advantages PBL has over traditional methods, including, improving the ability to validate reasoning with clear arguments; developing a high ability to plan a project, after working on a corresponding challenging problem; improving the achievements of students who find it difficult to study by traditional teaching methods; improving critical thinking and social abilities skills; improving the field of knowledge and content and developing learning capabilities; improving the development of group skills; and improving information literacy as well as developing flexible and useful knowledge, which encourages exploration and self-reflection.

Findings have also showed that the PBL approach enables greater involvement of the students in the field of knowledge. Teachers reported that focusing on realistic problems enables weaker students to share their knowledge in the field of study. Teachers also reported a reduced need for disciplinary intervention during the lessons, since the students are much more involved in the learning process. Several of these studies indicated significant academic impact that were evident mainly among the mediocre and weaker students, as shown in [18].

In the study described in [19] however, the findings were quite different. In their study, teachers reported that with the improvement in required skills, such as responsibility and problem-solving skills, there is also improvement in critical thinking and collaboration skills. The ability to learning new knowledge and content, however, received the lowest score in this study. The study also indicated that there are other disadvantages to the PBL approach. For example, during the initial stage, students don't relate to critical features of problems and they do not employ effective problem-solving strategies. An additional finding indicated that the PBL approach, which puts much of the responsibility on the student, may lead to a situation in which goals are missed out and misconceptions are maintained due to the lack of strategic intervention and guidance by the teacher.

The implementation of the PBL approach is a challenge for any teacher, since it requires implementation of changes in all the central aspects, such as teaching and teaching strategies, the curriculum, and the role of teachers and students in the teaching process ([4]). The approach is based on the notion of changing the focus from encouraging the search for "correct and certain answers" to the process of finding and formulating the answer. Hence, this approach involves a change in the perception of the teaching process, and a change in the perception of the essence of teaching as enabling the creation of different learning opportunities. In other words, the teacher is no longer the provider of knowledge, rather he is a project manager and a guide to solve problems as presented in [20]. This study, conducted among teachers during their first year of teaching PBL, indicated the importance of preparing teachers for change in the manner by which their work is carried out, as well as the importance of guiding teachers through this process. The findings of this study show that these changes cannot be implemented quickly and easily, since the teachers' natural inclination is directly related to the

way they perceive the essence of teaching, that is, what he or she consider as the purpose of teaching. When teachers are required to make a change in the way they teach, their initial inclination is a sort of a filter as to the way they will adopt the innovative learning method. In addition, studies that focused on teachers' dilemmas (as seen in [19]) that arise as part of the implementation of the PBL approach, found that teachers, who need to implement a project that was imposed on them as part of the curriculum, are often confronted with dilemmas, such as how they should act, and they also had to decide whether to stay true to their believes and way of work, or whether they should teach the project according to the given process.

The characteristics of the PBL approach, which situates the teacher at the position of the project facilitator, rather than the holder of knowledge, pose dilemmas that teacher must confront, although they don't always know how to solve them. Such a dilemma concerns the control of information, whereby teachers need to decide whether they will control the flow of information in order to ensure that the students' understanding will be properly structured, or whether they should allow the students to construct their own knowledge actively. Such a dilemma can lead to more substantial question relating to the question of responsibility, that is, should students be responsible for their learning or should teachers take responsibility for guiding the activities and providing the knowledge, or whether students be allowed to seek a variety of answers, or will the teacher direct the students towards certain answers. Another dilemma that arises by employing the PBL approach relates to the time devoted to learning versus the time devoted to the output, the product. Since the PBL approach requires more time than traditional teaching, in which the teacher is the central figure, the PBL approach raises the eternal question of the scope of the material studied versus the depth to which each topic is studied.

Another example relates to a dilemma in which the focuses is on the teachers. It concerns to the set of skills required by teachers, who need to manage several activities at the same time and master many areas of knowledge, making the teaching more complex. Many projects use technologies such as simulations, research using the Internet, or online collaboration between students in different places. All these activities pose additional demands from the teachers.

Based on all of the above, it appears that the teacher, whose role changes to a project guide and manager, must have skills that are different from those required of the "traditional" teacher. He or she should be able to manage the classroom, acquire extensive knowledge in the discussed field, set clear learning goals, and anticipate possible difficulties that may arise in the course of the learning process.

Moreover, the teacher should be willing to support the students according to their individual needs, to demonstrate understanding and tolerance for the diversity of each student, and to have a positive that encourages interactions with the students. These are numerous and complex skills, which may be natural for some teachers yet complicated for others that may be hesitant about the subject ([18]).

Therefore, in order to enable a good assimilation of the PBL approach within the school system, especially in terms of teachers' attitudes towards the subject, a systemic change must occur. Such a change will provide teachers support and the optimal conditions in order to successfully implement the new learning approach. This can be achieved when through collaboration and a commitment by the entire staff to the subject at hand. In this way, it is possible to expand pedagogical support for teachers, by providing technological support and assistance in curriculum development, making the technology a cognitive tool and not merely a study aid ([19]).

Systemic change, however, is not sufficient. In order to be effective, the teachers must understand the concepts and ideas inherent in the project, and they must be able to demonstrate to the students thinking and problem-solving strategies in a qualitative manner. The teachers need to accomplish this task with staff training and guidance of the teachers by employing PBL assimilation and work processes.

In the past decade, the teaching of the robotics profession has expanded greatly in Israel's education system. The pace of demand for robotics teachers, as part of the change in skills required in the 21st Century, was higher than the rate of teachers training for robotics. In addition, in recent years there has been a decline in the teaching of technological subjects in high schools in Israel. This decline has reduced the number of teachers with a professional background in engineering, science, and technology ([21]).

As a result, school principals recruited teachers without appropriate disciplinary training to teach robotics using PBL. They did so based on the assumption that teachers, who are requested to teach according to PBL principles don't need to have expertise in the field of content. In most cases, principals preferred educators (class tutors) over professional teachers, because of the ecological orientation of educators required by the project, an orientation manifested in the relationships with elements within the school and the community and with parents involved in the PBL projects. This led to a situation in which some of the teachers leading PBL projects had the appropriate disciplinary background, such as engineering, programming, and physics, while others, mainly educators, had no relevant background. This reality created a natural opportunity to examine the extent to which unique professional knowledge is required for teaching the robotics profession according to the PBL approach. Therefore, out of all the studies carried out on the subject, this study attempts to examine how do teachers perceive the PBL method, their satisfaction level and their sense of competence. The study also examines how teachers who teach robotics by employing the PBL approach evaluate the contribution of learning. In addition, the present study makes use of this opportunity to examine the significance of the teaching of robotics according to the PBL approach, by comparing the attitudes of educators to the attitudes of professional teachers in regard to aspects of general satisfaction and a sense of self efficacy to teach robotics. A further comparison was conducted between the perception of the professional teachers of humane and science professions to that professional engineering teachers. The current research knowledge relating to optimal learning processes in the teaching of robotics is limited. Therefore, this study can contribute to a better understanding of the field that is currently expanding.

2 Methodology – examining the robotics PBL effects on engineering education

2.1 Preliminary outline

The study was conducted in junior high schools in Israel, where the teaching of robotics took place in an extracurricular framework, but within the curriculum of science and technology. Most of the teachers were recruited by the school's principals, and some of the teachers even participated in their own initiative. Most teachers do not engage in science teaching or in teaching technology. This study was based on quantitative research principles from the assumption that it can also be applied to different populations. The premise of this study is that the best way to understand phenomena is by using a large sample and numerical measurement (N = 176), which is required in order to avoid a result that may reflects only a partial view of the matter at hand when focusing on only a few limited cases.

2.2 The research questions and study population

The research questions were as follows:

1. What are the levels of satisfaction and sense of self efficacy of teachers who teach robotics using the PBL approach?
2. How do teachers, who teach robotics using the PBL approach, assess the contribution of learning in relation to three aspects: personal, professional and ecological? Are there any differences between the three aspects as to the contribution following the experience of teaching PBL?
3. What are the differences between educators and professional teachers in their perceptions of PBL in relation to their satisfaction level, sense of self efficacy, and assessment of the contribution of learning?
4. What are the differences between teachers in three fields of knowledge: engineering, sciences and humane studies with respect to the PBL: satisfaction, sense of competence, and assessment of learning contribution?

The study involved 176 teachers composed of 44% male and 56% female participants, who teach robotics in middle schools. 40% of the teachers are class educators, and the rest are professional teachers. 36% of the participants teach engineering subjects, 32% of them teach humane studies, and the rest teach science. As to the level of education, 49% of the teachers have a bachelor's degree, 33% are MA graduates, 5% of the teachers have a doctorate, and the remaining participants have tertiary education. 77% of the participants have 1-5 years of experience guiding projects, 1% have more than 10 years of experience and the rest have 6-10 years of experience. More than 2/3 of the teachers (68%) underwent professional training on the subject of PBL. These characteristics are seen in Fig.2.

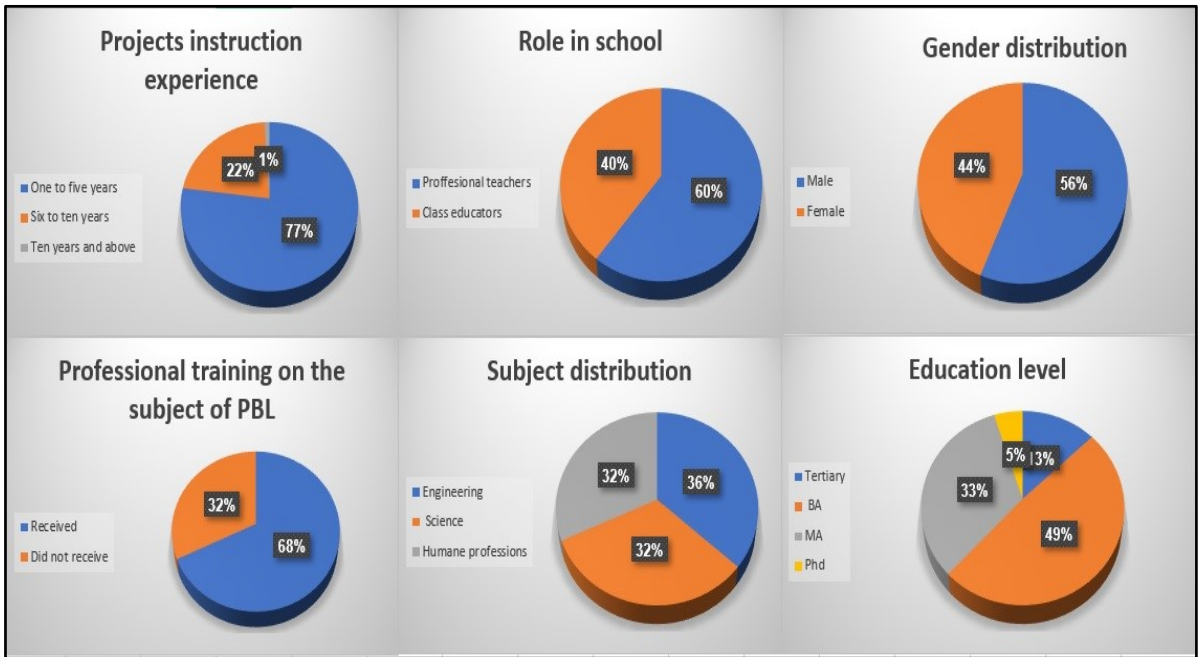

Fig.2: The distribution of the study population

2.3 Tools

The quantitative data was collected using a structured questionnaire developed for the study. The purpose of the questionnaire was to examine teachers' attitudes toward teaching robotics using the PBL method. It included personal characteristics, satisfaction and sense of efficacy, and their perceived contribution of the PBL approach. In the closed questions, participants were asked to rate statements using a six-point Likert scale. The participants also answered open questions.

In the section of satisfaction and sense of efficacy, two measures were constructed:
Satisfaction - the statements: I am pleased that I lead projects; I see myself as a project facilitator in five years; and I will also recommend my colleagues to lead such projects. In Cronbach's alpha reliability level 0.844, the average satisfaction level is 4.98, and the standard deviation is 1.09.
Sense of efficacy - the statement: I have good knowledge of robot programming is good, I have good knowledge of building robots; and I have good knowledge of leading projects. In Cronbach's alpha reliability level 0.802, the average sense of efficacy is 4.22, and the standard deviation is 0.86.
The section in the questionnaire for evaluating the personal contribution to projects was based on Vonk's theoretical model ([10]). He divided the work of teachers into three aspects: personal, professional and ecological. Accordingly, statements were formulated describing the contribution of learning in each of the three aspects. The following details the aspects in the questionnaire:

Personal - the statements: Contribution to the development of your creativity; Contribution to your enjoyment of teaching; Contribution to your independence in teaching; and Contribution to the improvement of your thinking skills. Cronbach's alpha reliability 0.92.
Professional - the statements: Contribution to your professional development; Contribution to your knowledge of teaching robotics; Contribution to the students participating in the project; Contribution to your relationship with the students participating in the project; and Contribution to creating a positive atmosphere in the classroom. Cronbach's alpha reliability 0.61.
Ecological - the statements: Contribution to receive certain positions in the school; Contribution to the communication with the parents of the students participating in the project; Contribution to the students' knowledge and understanding of a different type of learning; Contribution to the reputation of the school; Contribution to your relationship with other teachers teaching the program; and Contribution to the creation of a culture of action. Cronbach's alpha reliability level 0.67.

	Educators		Professional teachers		Total	
	Avg	**Std. D**	**Avg**	**Std. D**	**Avg**	**Std. D**
satisfaction	4.91	1.24	5.04	0.98	4.98	1.1
sense of efficacy	4.36	0.89	4.13	0.89	4.23	0.9
personal contribution	5.13	1.08	4.89	1.05	4.99	1.07
professional contribution	5.1	0.85	4.95	0.94	5.01	0.91
Ecological contribution	4.69	0.7	4.24	0.8	4.43	0.79

Table 1: the averages and standard deviations of satisfaction and sense of efficacy. In addition, the assessment of contribution in the entire sample, and the relation between educators and professional teachers separately.

	Engineering		Science		Humane Studies	
	Avg	**Std. D**	**Avg**	**Std. D**	**Avg**	**Std. D**
satisfaction	5.18	0.92	5.05	1.2	4.79	1.14
sense of efficacy	4.11	0.81	4.31	1.07	4.27	0.86
personal contribution	4.83	0.98	5.05	1.28	5.08	1
professional contribution	4.9	0.73	5.09	1.1	5.05	0.91
ecological contribution	4.11	0.74	4.55	0.89	4.62	0.7
general score	4.62	0.83	4.81	1.1	4.76	0.92

Table 2: the differences between teachers in the three fields of knowledge

These three general measures were calculated using the average responses to the statements included in each category. In order to test the validity of the three categories, Pearson correlations were calculated among the three. Significant positive correlations were found with medium-high intensity, ranging from 0.50 to 0.75. This result indicates that the three categories are interrelated, but each has a unique meaning.

3 Findings

The averages presented in Table 1 indicate a high level of general satisfaction with the teaching using the PBL approach (almost 5 on a six-point scale).

The sense of efficacy level is medium-high, with an average of 4.2. The contribution in relation to the personal and professional aspects was perceived as high (average around 5), and the contribution in relation to the ecological aspect was perceived as medium-high.

For examining the significance of the differences in the contribution of the three aspects, a variance analysis was performed with repeated measurements and a Bonferroni correction test. The analysis of variance revealed a significant effect of the type of contribution:

$$F\ (2,173) = 41.57,\ p< 0.001,\ \eta^2= 0.32$$

The Bonferroni test showed that the source of variation is the difference between the ecological contribution, which is perceived as lower, and the perceived contribution in the personal and professional aspects.

To examine the differences between educators and professional teachers, a multivariate variance analysis was conducted in which the independent variable was the role (educators, professional teachers), and the dependent variables were the five measures (shown above in Table 1) of the perceptions of PBL. A significant effect was found in the multivariate analysis:

$$F(5,179) = 3.48,\ p < 0.005,\ \eta^2 = 0.09$$

This effect is due to the fact that the educators' perceptions of the PBL approach are more positive than those of the professional teachers.

The single-variable analysis showed a significant difference in relation to the ecological contribution:

$$F(1,174) = 15.15,\ p < 0.001,\ \eta^2 = 0.08$$

This difference is due to the fact that educators perceive the contribution as higher than professional teachers.

For examining the differences between teachers in the three fields of knowledge mentioned above, averages and standard deviations were calculated for the five indicators: satisfaction, sense of efficacy, and personal, professional, and ecological contributions, among teachers from the three fields of knowledge: engineering, science, and humane studies. The analysis of the answers was based on a six-point Likert scale. The findings are presented in Table 2.

A multivariate variance analysis was performed, in which the independent variable was the teaching role (engineering, science, and humane studies), and the dependent variables were the five measures of the perceptions of PBL. A significant effect was found in the multivariate analysis:

$$F(10,340) = 2.63,\ p < 0.004,\ \eta^2 = 0.07$$

An examination of the general averages of the general grade shows a higher average among teachers of the science, and humane studies professions than among teachers of the engineering professions.

In the single-variable analysis, there was also a significant difference in the perception of the ecological contribution:

$$F(2,173) = 8.10,\ p < 0.001,\ \eta^2 = 0.09$$

In order to examine the sources of the differences, Tukey-type posteriori was performed at significance level 0.05, and it was found that the perception of the ecological contribution of the PBL learning environment was also higher among teachers of the science, and humane studies professions than among teachers of the engineering professions.

In order to predict the satisfaction of all teachers from the experience of the teaching PBL, a multiple regression analysis was performed, with the satisfaction score being predicted. The predictors were: a sense of efficacy, professional training, role, field of study taught, and seniority. The results are presented in Table 3.

Multiple correlation at medium-high level was found between satisfaction and all predictors, with the strongest predictor being the sense of efficacy. In addition, the higher satisfaction was found among trained teachers, teacher with seniority in the school and leading projects, and teachers who do not teach the humane studies professions.

In order to predict the assessment of the contribution of the experience in each of the three above aspects, when employing the PBL approach, multiple regression analyses were conducted, with the predictors being the same as those in the regression analysis performed for satisfaction.

Various patterns of predicting the ecological contribution were found, as opposed to the personal and professional contributions.

Personal and professional contributions are related, in addition to efficacy, to professional training as well. On the other hand, the ecological contribution is not related to training, but rather to the teaching of the humane studies professions.

In other words, teachers who are not professionals in the teaching of robotics, perceive the contribution to the school and the environment as more meaningful.

The results of the assessed contribution of the experience in each of the three aspects are seen in Table 4.

Predictor	Beta	Significance	multiple correlation
sense of efficacy	0.51	0.001	***0.62
professional training	0.17	0.01	
role (educator / professional teacher)	0.03	NA	
humane studies	-0.21	0.01	
science	-0.1	NA	
teaching seniority	-0.23	0.06	
seniority at the school	0.29	0.02	
seniority in leading projects	0.29	0.02	

Table 3: predicting teachers' satisfaction from the experience of PBL

Predictor	Personal contribution		Professional contribution		Ecological contribution	
	Beta	Sig.	Beta	Sig.	Beta	Sig.
sense of efficacy	0.93	0.001	0.7	0.001	0.53	0.001
professional training	0.06	0.05	0.2	0.001	0.02	NA
role (educator / professional teacher)	-0.001	NA	0.02	NA	0.1	NA
humane studies	-0.002	NA	0.038	NA	0.16	0.05
science	0.03	NA	0.04	NA	0.14	NA
teaching seniority	0.01	NA	-0.07	NA	0.16	NA
seniority at the school	0.09	NA	0.12	NA	0.04	NA
seniority in leading projects	0.05	NA	-0.001	NA	-0.21	0.003
multiple correlation	R=0.93		R=0.72		R= 0.66	

Table 4: The results of the assessed contribution of the experience in each of the three aspects

The participants in the study were asked to answer an open question in which they had to complete the sentence: "Teaching robotics for me is ..." A preliminary review of the responses revealed an interesting finding, which was expressed in the fact that most teachers did not relate in their responses to the field of robotics directly. Most of them described experiences related to teaching, and some of them explicitly referred to teaching PBL.

A detailed examination of the answers revealed that the experience is composed of several dimensions, including: a sense of challenge ("pure fun, although there are few complex moments, an unusual challenge, demanding, enriching, and fascinating"), a sense of significance and mission, personal and professional empowerment (an empowering experience for both teacher and student"), and emotional pleasure.

At this stage, a theory-driven analysis was conducted, in which the categories were defined in advance and they were derived from the Vonk's theoretical model ([10]). The purpose of the analysis was to demonstrate the three dimensions of Vonk's model: the personal, professional, and ecological, as these are reflected in the experience of the teaching PBL. The answers of the teachers indicate that there is evidence of each of the three aspects. Examples of such statements for each of the three aspects discussed are as follows:

Personal:

- "To be able to move myself from the centre, become a teacher who coaches/guides, and even become a colleague for learning."
- "An empowering experience for the teacher and the student."
- "Learning together with children younger than you."
- "It's fun, I learn from the kids."

Professional:

- "To understand that, today, you can learn all fields of knowledge in an experiential and enjoyable way, that involves activities, and not only the study to pass a test."
- "A great opportunity to teach project-based learning."
- "A new type of learning that has a lot of ambiguity."
- "When you succeed you can see through the children's eyes."

Ecological:

- "To know how to tell a story, it feels like writing a book from beginning to end."
- "It's like being a driver, since I have to control my car, to know the driving requirement in the street I'm driving, you need to re-program from the beginning the things I need to do and overcome the difficulties on the way."
- "A way of life, a social mission."
- "To give them personal experiences and connections that can only be created by the teamwork of a unique group."

4 Discussion and Conclusion

Robotics is a defined professional field that requires unique professional knowledge and the use of advanced technology. That being said, middle school principals recruited, for the robotics courses according to the PBL approach, teachers from different fields of knowledge, most of whom had no prior background in robotics and only participated in a short training course. They based this decision on the assumption that the PBL approach enables teacher, who have no expertise in the field of knowledge, to successfully lead the project. The present study examined this assumption by examining how teachers perceive their experience teaching according to the PBL approach. The robotics profession was chosen to be the research field, as it represents a much broader question relating to the characteristics of PBL teaching and its implications for teachers' teaching experience.

The findings showed a medium to high levels of a sense of efficacy, which can be explained by their lack of knowledge and experience in the specific field of knowledge. There was, however, a high degree of general satisfaction, which was described verbally, in strong expressions of enthusiasm and a sense of challenge. An analysis of the responses to the open question shows that satisfaction was high due to the unique characteristics of the PBL teaching experience. The main characteristic of the role of teachers in the teaching of the PBL was expressed in the management of the project, which was manifested in the tasks of directing and encouraging students, recruiting experts in the field of knowledge, creating relationships with the surrounding (management, peers, parents, etc.) and solving problems that arose during the project.

The findings suggest that a successful experience in the management of the PBL, no expertise is required in the unique disciplinary field, but rather management skills, flexibility of thought, and the ability to collaborate with the school staff. This conclusion is consistent with existing literature in the field of PBL teaching ([20]).

The present study reinforces the generalization of this conclusion by providing supporting evidence in an additional field of knowledge. In order to describe the success of project management in theoretical terms, the study examined the findings of the contribution to teaching, using Vonk's model ([10]). This model offers three aspects, in which the professional activity of teachers is expressed: professional, personal and ecological. The findings showed that among all teachers the professional and personal contributions are perceived as high (the averages are very close to 5 on a six-point scale), while the ecological contribution is slightly lower.

It is reasonable to assume that this finding reflects the relatively high proportion of the ecological component in the teachers' experience of managing PBL. That is, the relationship with the environment (teachers unrelated to the project, parents) is not dominant relative to the professional component of managing learning (the relationship with students) and to the personal aspect (expanding the sense of efficacy). A more detailed analysis, however, of the comparison between subgroups of teachers who participated in teaching PBL reveals a more complex picture.

This analysis resulted in two interesting findings:

1. The ecological contribution of teaching according to the PBL approach is perceived as higher among educators than among professional teachers. It is reasonable to assume that this difference is anchored in the role of the educator, who is in constant contact with other teachers in the school and with the parents, rather than professional teachers ([21]). Such a situation enables the class educator to see the potential inherent in the ecological contribution of PBL, and to realize his capabilities in this field, such as raising human resources and other resources in the communities for the success of the project.
   The possible implications of this finding on the educator's work deviate from the disciplinary field of teaching robotics. It is possible to expand the traditional role of educators and assign them to project management in various fields of knowledge, thus enabling them to experience meaningful learning and teaching.
2. The findings indicate that professional teachers in the fields of science and humane studies report a significantly more positive experience of PBL than engineering teachers, and it is reasonable to assume that the lack of prior knowledge in the field of robotics and the PBL approach increased the perception of its contribution. It is also reasonable to assume that teachers' experience expanded the field of their professional knowledge. It enabled them to express skills they had not previously known, raised their sense of efficacy, and created an experience of challenge and significance.
   The process shows that the educators underwent a second-degree change, which gives a more meaningful experience. In contrast, professional engineering teachers perceived the experience of PBL in robotics as a continuation of their traditional teaching, and therefore did not exhibit similar enthusiasm as their colleagues from the other disciplines.

A limitation of the present study is expressed in the fact that it is based on the perspective of one of the participants in the learning – teaching process, the teachers, who guided the project. The students' perspective has not been studied. It is required to continue the study and examine the perceptions of the students who participate in PBL classes in which the teachers are not experts in the field of knowledge.

One of the practical implications of this study concerns the professional training of teachers who are intended to teach using the PBL approach. It seems appropriate to devote more attention in these training on project management skills and avoid limiting the learning to enriching knowledge in the specific field.

Another recommendation is to avoid limiting the selection of staff that is intended to lead the PBL to professional teachers, rather also include educators and teachers from different fields of knowledge. Such diversity may help enrich teachers' role and enhance their sense of belonging to the teaching world.

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