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Research Article

First-year engineering students' affective behavior about mathematics in relation to their performance

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ABSTRACT

The present study examines the first-year engineering students' attitudes towards mathematics, their beliefs and self-efficacy about mathematics, as part of their affective performance, in relation to their mathematical academic performance before and after attending an introductory mathematics course. It aims to contribute on the ongoing discussion about the teaching of mathematics at the level of higher education in engineering programs. First-year engineering students completed a questionnaire and a test after their entrance at the university. Their mathematical performance was examined by using their results at the midterm and the final mathematical mark during AMAT111 course offered at the first semester of their studies. Results indicated that aspects of the affective domain were related with students' performance, while the predominant role belonged to their previous mathematical knowledge and skills (as learning outcome of the high school education), which undoubtedly need further enhancement. The belief about a formalistic perspective of mathematics and the lack of understanding of the implementation of the mathematical concepts on engineering problem solving situations were obstacles for them on recognizing the importance of attending mathematics courses as part of their engineering studies. Discussion concentrates on the following up steps, which have to be done at the level of higher education in order to face the initial difficulties, which have been identified.

Keywords: engineering mathematics, beliefs, self-efficacy beliefs, attitudes

INTRODUCTION

Teaching mathematics to new entrance engineering students remains an issue of discussion in higher education for many decades and probably will always remain, as the teaching processes will always be discussed in relation to the assessment methods and the introduction of innovations. We always need to identify the students' and the teachers' difficulties, interpret them and try to overcome them by implementing more effective teaching processes and by using more suitable and attractive teaching tools. We can find references with those academics' concerns and barriers about the teaching of mathematics in engineering courses many decades ago, starting from the Woodward et al.'s (1908) publication with the title "The teaching of mathematics to students of engineering: What is needed in the teaching of mathematics to student of engineering? Range of subjects, extent in various subjects, methods of presentation and chief aims". Research undergraduate mathematics education in 2019 published a special issue about mathematics in /for engineering education. European Society for Engineering Education has established a special interest group in mathematics, which published a report in 2021 on "making sense of engineering workplace mathematics to inform engineering mathematics education". All the discussions either in the field of mathematics education or in the field of the teaching at higher education aim to contribute on finding appropriate and effective teaching methods, tools and processes for students with inter-individual differences concerning their abilities, previous knowledge, motivations, skills, beliefs, self-efficacy beliefs, conceptions, values and attitudes.

The review of the literature, which is presented by Pepin et al. (2021), as a metanalysis, indicated that many departments at university levels report on high drop-out rates in mathematics in the case of engineering students. Usually after discussions either at the level of the departments or at the level the Senate, there are decisions such as the offer of introductory courses to face the gap of the transition from the high school education to the university education. Eichler and Gradwohl (2021) argue that there are particular students' abilities on mathematics derived by their previous school life and there is a need for identifying them and develop a program of tutorials at the initial phase, either before or during attending a mathematical course, otherwise there are too many difficulties, which cannot be overcome during the following up levels of their studies.

Although mathematics is widely acknowledged as an important domain for the studies of engineering, it is not in engineering student's primary interest (Tossavainen et al., 2019). On the contrary, students do not seem to understand the relation of the mathematics courses with the basic domain of their studies and the applicability of the mathematical knowledge they acquire on their future professional work (Rahman et al., 2012). As Sazhin (1998) argues, mathematics should be regarded as a language for expressing physical and engineering either ideas or laws, by using symbols, diagrams, words and any other types of representations. At the same time, the heart of mathematics is the problem solving, which is characterized by real-life framework. Engineers at the real-life situations use knowledge and skills in order to solve problems with extremely practical implications. From the first semesters of their studies, engineering students need to understand the implementation of the mathematical knowledge on engineering problems they face as part of their studies. As Singh (2015) underlines, although the main goal of mathematics learning for engineering departments is to apply a wide range of mathematical techniques and skills in their future work, under a realistic framework with interdisciplinary characteristics, most of the students do not understand the implementation of the mathematical knowledge in problem solving situations, due to the lack of respective examples during the teaching.

The present study was developed during an introductory engineering mathematics course (AMAT111), after the discussion at a specific private university of the drop-out engineering students and their low performance in mathematics. It aimed to examine new entranced at the university engineering students' mathematical performance in relation to their beliefs about the nature of the mathematical knowledge, their self-efficacy beliefs in succeeding at mathematics and their attitudes towards mathematics. We believed that this could be the first phase in identifying the origins of the problem, which could enable us to suggest relevant intervention programs. All those aspects of students' affective behavior derived from their previous school experiences and probably impact directly or indirectly their cognitive and learning behavior. We aimed to examine the degree according to which the variation in their mathematical skills at the initial phase of starting their studies can be partly explained by those factors and how the introductory mathematics courses can empower them to face their difficulties and to successfully continue their studies. A motivation of the present study is the ongoing discussions between the engineers with the mathematicians about the prerequisites for the successful transition from high school education to higher education and the related knowledge and skills, which are necessary. A cooperation between academics in the domain of mathematics and academics in the domain of engineering is expected in order to offer the courses with the necessary content. Many times, the engineering faculty consider mathematics faculty as outsiders who cannot either understand the problem or propose suggestions for facing it (Margolinas & Drijvers, 2015), although they have the responsibility to offer the mathematical courses. Similarly, many times, mathematics educators do not try to introduce mathematical concepts at a real-life context with engineering applications.

We would like to examine further whether the initial differences in mathematics, which are expected to influence students' academic performance during their studies, can be partly explained by their previously established beliefs about the nature of the mathematical knowledge, their self-efficacy beliefs about mathematics in general and problem solving in particular, their attitudes towards mathematics and their previous mathematical knowledge and experiences. At the level of higher education, we cannot concentrate only on discussions of what could be done at the level of high school education, we have to discuss about our responsibility, on how we can create teaching environments, which can construct positive experiences in engineering mathematics based on their real knowledge, skills and previous experiences. We need to identify the difficulties, interpret them and try to face them. The purpose of the study has been divided into two main interrelated research questions:

RQ1. Which is the impact of the new entrance engineering students' previous mathematical knowledge and skills on their affective beliefs and performance during the attendance of a university mathematics course (AMAT111) on university mathematics?

RQ2. Which are the relations among engineering students' affective performance in mathematics and their academic performance in an introductory mathematical course (AMAT111) at the university mathematics?

LITERATURE REVIEW

Many previous studies have underlined the importance of mathematics education for engineering students and the necessity to develop relevant introductory mathematical courses. Usually engineering departments in cooperation with mathematics departments offer mathematics courses to the first-year engineering students during the first semesters of their studies in order to ensure the acquaintance of the basic mathematical knowledge and skills (Lopez-Diaz & Pena, 2021). Many of the compulsory courses in the engineering programs require certain mathematical concepts and skills, which can be offered as part of mathematics courses before or during the engineering courses. Nevertheless, Tossavainen et al. (2020) indicated that new entrance students at engineering programs are often unaware of how mathematically demanding their course would be. Their previous negative attitudes towards mathematics and the insufficient previous information led them to believe that they have chosen a course, where the mathematics would not be necessary.

Curriculum development at the engineering courses aims to develop the engineering students' skills to think mathematically and to use mathematics in order to describe and analyze different aspects of the real engineering world (Diane et al., 2015). However, many engineering students never understand mathematics due to insufficient knowledge or skills during their high school life or they never like them, and they believe that they have chosen a science, which is characterized by its implementation in real life situations, while mathematics is too abstract for them (Singh, 2015). Goold's (2014) study indicated that the majority of the engineering students are neither confident in their mathematics ability nor they demonstrate any value of mathematics in order to try to improve their abilities. For this reason, they aim only to pass the mathematics courses in order to be able to continue their studies. Their beliefs about the low value of the mathematical knowledge for their future work seems to be empowered by their experiences from engineering mathematics courses, where the teaching of mathematics is decontextualized, with a few references to engineering (Harris et al., 2015).

Higher education students, mainly engineering students, often lack the basic mathematical skills to follow the lectures and students do not have enthusiasm for learning. Song (2019) posted three main reasons for this phenomenon:

1. Mathematics itself has certain difficulty.
2. Teaching methods are boring.
3. Teacher's mathematics quality still needs to be improved.

The emphasis on the basic knowledge and skills without a realistic context is usual at the teaching of mathematics at the upper level of high school education and it is not expected to be continued at higher education. As we have already mentioned, the transition from high school to higher education has been considered in several studies (Tossavainen et al., 2019, 2020), by revealing the different motivation, expectations, methods of teaching, methods of assessments etc. In the case of mathematics, the emphasis on traditional and formalistic perspectives prevents the implementation of innovative teaching and learning processes, characterized by interdisciplinarity, applicability and inquiry-based context.

Mathematics is often considered as a subject that students find hard to understand due mainly to their experiences during high school education and the emphasis on symbols and procedural perspective of knowledge. Therefore, many universities are faced with the problem that new entrance students drop out one or two semesters after the start of their studies due to mathematics (Lithner, 2011), mainly when they realize that their studies have difficult, compulsory mathematical courses. Bengmark et al. (2017) examined the initial and the continuous aspects of self-efficacy beliefs, motivations, habits and the beliefs about the nature of mathematics. They indicated that those factors explained students' performance at the beginning of their studies, while at the end of the first year, their self-efficacy beliefs became the predominant predictor of their performance, as they realized their strengths and limitations in order to face and overcome the related difficulties.

Undoubtedly active learning has a positive effect on students' motivation, active participation and consequently academic performance (Lopez-Diaz & Pena, 2021). However, it is not easy to activate all the new entranced students, especially at a course, which is not related directly to their main interest. Rensaa (2018) presents deliberately chosen mathematical episodes observed in a class of engineering students taking a basic calculus course in order to examine the accountability of different teaching processes. Based on the results, it seems that instrumental strategies can serve as valuable parts of the learning environment in engineering education. To overcome the difficulties many universities have developed academic support courses as part of informal learning, through their website (online lectures, notes, and videos), which are suitable for students who have high metacognitive knowledge of their difficulties and aim to overcome them. Those programs have to be examined about their effectiveness.

Mathematics education calls for the development of curriculum with emphasis on the conceptual understanding, the problem solving and the project-based knowledge and the inquiry-based teaching. Saiman et al. (2017) examined whether the emphasis in mathematics courses for engineering students would benefit from emphasizing more on the conceptual knowledge than the procedural knowledge. Teaching with a focus on conceptual understanding is based on constructivism and it may start by providing a contextual basis for the new mathematical knowledge requiring students to connect the new knowledge to their prior established knowledge and to problem solving situations, where they need to implement it. It was impressive that although mathematics education calls for emphasis on problem solving and the conceptual understanding of the mathematical concepts, their results showed that most of the engineering students felt that conceptual mathematics was less important than procedural mathematics for their future job and they found it more demanding for their assessment. It seems that they consider mathematics as a permanent vehicle in order to be transferred at the useful engineering knowledge.

We believe that in order to be able to propose more effective teaching methods we need to understand a part of the learning obstacles, which prevent students from being active and productive learners in engineering mathematics. It is important to realize students' beliefs and conceptions about the teaching and learning processes. A dimension of students' cognitive behavior is based on the affective domain. The affective domain is a complex structural system (Charalambous et al., 2009), consisted of emotions, attitudes, beliefs and values (Goldin, 2002). The present study concentrates only on few aspects of the affective domain: beliefs, self-efficacy beliefs about mathematics and attitudes towards mathematics. Attitudes show one's disposition about an issue. Compared to beliefs, "attitudes have a stronger affective component, a weaker cognitive component and are of moderate intensity and stability" (Charalambous et al., 2009, p. 164). Beliefs can be described as one's subjective "understandings, premises or dispositions about the world" (Philipp, 2007, p. 259). Beliefs vary significantly and they concern the nature of mathematics, students as learners of mathematics and the meaning of individual mathematical notions (Tossavainen et al., 2017). A part of those beliefs are the epistemological beliefs about the nature of the mathematical knowledge and the ways for gaining it. Ernest (1991) suggests a model with three categories of epistemological beliefs:

1. Platonic approach considers mathematics as an a-priori static unified body of language.

2. Instrumental approach regards mathematics as a set of rules, algorithms, and operations.
3. Experimental approach, which views mathematics as a dynamic field of human creation.

The formalistic perspective of mathematics relates the platonic and the instrumental perspective as it emphasizes the static nature of mathematics with symbols, structure and rules that have to be used strictly.

The efficacy beliefs are based on Bandura's (1993) longitudinal work on social psychology. Bandura (1997) defines self-efficacy beliefs as one's perceived ability to plan and execute tasks to achieve goals. Bandura (1993) stated that students' targets and ambitions, levels of motivation and academic performance are driven by their self-efficacy beliefs to regulate their own learning. Based on this theory a student with high self-efficacy beliefs in mathematics gets the challenge to overcome the difficulties, which are faced during the attempts to solve a mathematical task, by using effective self-regulatory strategies, while a student with low self-efficacy beliefs in mathematics tend to avoid this kind of a task (Tossavainen et al., 2019), or asks for external contribution (from a teacher or an adult). Probably many first-year engineering students struggle with mathematics courses and their low performance compels some of them to change their career aspirations (Zakariya et al., 2020), by using the usual behavior of not trying to face and overcome the difficulty.

METHODOLOGY

60 first year engineering students at a private university in Cyprus constituted the sample of the present study. They had to attend an introductory, obligatory mathematical course (AMAT111) during the first semester of their studies at school of engineering (fall semester 2022). Their studies could be on computer engineering, mechanical engineering, civil engineering, and electrical engineering. The content of the course, as it presented formally at the university website, included mainly the following concepts:

- Exponents, roots their properties. Exponential and logarithmic equations.
- Basic trigonometric functions and their graphs.
- Real valued functions of one variable. Graphs of linear, quadratic, cubic, square root, exponential and logarithmic functions.
- Limits and continuity.
- Differentiation: the derivative as a function, as a rate of change and as the slope of a graph, techniques of differentiation, chain rule, derivatives of trigonometric, exponential and logarithmic functions.
- Application of differentiation: related rates, curve sketching, maximum and minimum.
- Introduction to the concept of integration

Firstly, the academics of the mathematics course explained to the students the purpose of the present study and they asked them to sign if they accepted to participate in the study. Eventually 48 boys (80.00%) and 12 girls (20.00%) took part at the study (the initial sample was 68 students; however, eight of them did not take part at all the phases of the study and the respective data were excluded). The students who attended the AMAT111 were accepted for studies at the programs of the school of engineering without the need to pass entrance exams (a usual policy at public universities). They just needed to submit a high school leaving certificate from high school education without being obliged to attend specific courses at the high school (e.g., mathematics or physics or technology). Although this is not a usual policy at higher education in general, it is a usual practice in the case of private universities, which aimed to offer the opportunity for studies to all people.

In order to examine the two posed research questions, we had developed

(a) a questionnaire about students' affective behavior towards mathematics (presented at Charalambides et al., 2023) and

(b) a test about their initial mathematical performance before attending introductory course AMAT111.

The questionnaire was consisted of three parts. Firstly, few demographic information was asked (gender, course, type of previous high school education, their mathematical mark at the final grade of high school, and their overall final mark of the high school diploma). The second part consisted of 20 Likert type items on their beliefs about mathematics (1=totally disagree, 2=disagree, 3=neither agree nor disagree, 4=agree, and

5=totally agree). The third part consisted of 18 items with the same Likert scale, on their self-efficacy beliefs about mathematics and their attitudes towards mathematics. The test on their mathematical performance consisted of 15 tasks, which involved different mathematical concepts, related to basic concepts, which were taught either at the lower or the upper secondary school. Finally, their following up mathematical performance was measured by sing their mark at a midterm test and their final mark at the course AMAT111 (the tests for the midterm and the final exams were developed by their academics).

SPSS (version 25) was used for the data analysis. Firstly, the items of the questionnaire were classified into factors, by using exploratory factor analysis. Then the means and the standard deviations (SDs) of those factors were calculated in order to be examined in relation to the mathematical performance. Additionally, the sample was splinted into three cluster (low, medium, and high performance), in respect to their initial mathematical performance in order to examine the impact of those dimensions on students' affective and academic performance.

Limitations

As we have already mentioned participants needed to accept participating at the study and no reward was given. We analyze the characteristics of the participants without knowing the characteristics of those who denied to participate and the reasons for doing that. A second limitation is based on the exclusive use of the questionnaire for the examination of the beliefs, self-efficacy beliefs and attitudes, without being sure about their inner thoughts, which could be revealed through a detailed interview.

RESULTS

Factor analyses were conducted for the second (KMO=0.832, $p<0.05$) and the third part (KMO=0.769, $p<0.05$) of the questionnaire. In both cases the analysis was conducted under the restriction of eigenvalue greater than one. The analysis of the students' responses to the items about the students' beliefs resulted in five factors, which explained the 67.75% of the total variance and the respective analysis of the items about self-efficacy beliefs and attitudes towards mathematics resulted in three factors, which explained the 73.56% of the total variance. The content analysis of the items (Charalambides et al., 2023) of the eight factors resulted into the following factors:

- **F1.** Success in mathematics (seven items, e.g., some people are not able to learn mathematics),
- **F2.** Mathematics in real life (two items, e.g., mathematics are related with everyday life),
- **F3.** Problem-solving (four items, e.g., speed of solving a mathematical problem is not important),
- **F4.** Formalistic perspective of mathematics (four items, e.g., mathematics is a set of rules),
- **F5.** Experimental perspective of mathematics (three items, e.g., in mathematics there are not any absolute truths),
- **F6.** High self-efficacy beliefs (seven items, e.g., challenge of mathematics is attractive to me),
- **F7.** Negative attitudes towards mathematics (seven items, e.g., mathematics is a tough subject), and
- **F8.** Positive attitudes towards mathematics (four items, e.g., I usually enjoyed studying mathematics at high school).

The means and SDs of the eight factors are presented at **Table 1**. The highest mean in the case of students' beliefs about mathematics (3.75) was found at the items, which expressed a formalistic aspect of mathematics (**F4**). However, in all cases participants indicated high beliefs, even in the case of the contrary to the above-mentioned aspect about the experimental perspective (**F5**). Similarly, in the case of students' self-efficacy beliefs about mathematics and attitudes towards mathematics, results indicated that students had extremely negative attitudes towards mathematics (4.30) and, as it was expected, at the same time they did not have high self-efficacy beliefs (2.56) about their abilities at mathematics. The low SD in each case (0.45-0.70) indicated that the sample behaved by a consistent way.

Based on the posed research questions, we have examined the relation of students' previous mathematical performance (high school mark) with their initial mathematical performance (at the test), the dimensions of the affective domain examined at the present study, and their mathematical performance

Table 1. Mean & standard deviation of factors about students' affective behavior

	Factors	Mean	Standard deviation
Beliefs about mathematics	F1	3.04	0.44
	F2	3.52	1.05
	F3	3.05	0.47
	F4	3.75	0.55
	F5	3.15	0.61
Self-efficacy beliefs & attitudes	F6	2.56	0.78
	F7	4.30	0.45
	F8	2.36	0.70

during and at the end of the semester (course marks). The results about the previous mathematical performance (at a scale up to 20), as was expressed by their mark at the high school, indicated that the students could be divided into four groups: 1st group: mark 19-20 four students, 2nd group: mark 16-18 23 students, 3rd group: mark 3-15 20 students, and 4th group: mark 10-12 11 students.

The results confirmed our initial thought that many students choose their studies without having high performance on mathematics. 31 of the 60 students had a mark under 15 (at a scale up to 20). Additionally, the mean of the students' overall mark at the high school was 15.79 and SD was 1.68. Before attending the AMAT111, the students' mean performance (the scale was 0-15) at the initial mathematical test was 8.32 (SD=2.28, minimum=1.50, and maximum=12.08). Those results confirmed the difficulties that students faced when they were asked to solve mathematical tasks based on their knowledge derived by secondary education. There was a statistically significant relation between students' performance at the initial test and their total performance (overall mark) at the end of the high school ($r=0.505$, $p<0.01$).

Finally, we aimed to examine the relation of their affective and academic mathematical performance in relation to their initial performance at the test. For this reason, students were divided into three clusters according to their initial performance at the mathematical test: 12 students with low performance, 28 with medium and 20 with high performance. Analysis of variance was used in order to examine any statistically significant mean differences. Results indicated that students with low performance in mathematics believed more than the other groups in the formalistic nature of mathematics and less in the use of any experimental learning process. Even in the case of the students with high performance in mathematics the mean of the beliefs about a formalistic perspective of mathematics was high (3.65) and similar to the mean of the belief about an experimental nature of the mathematical knowledge (3.66).

The similar analysis about students' attitudes and self-efficacy beliefs indicated that students with high performance on mathematics did not have the highest self-efficacy beliefs (2.84) as they might not have a precise self-image about their abilities. They had the less negative attitudes towards mathematics (3.52) and the highest positive attitudes (3.02). Both groups of students with low and medium performance on Mathematics had the most negative attitudes towards mathematics. It is important that although the differences could not be compared statistically (due to the small sample) a tendency of students with medium performance to overestimate their performance was revealed. The specific group of students expressed the most positive self-efficacy beliefs (3.26), probably due to their lack of precise self-image about their mathematical abilities or their tendency to believe that by this way they affect positively the surrounding peoples' beliefs about them and their abilities.

As we have already mentioned, the following up students' mathematical performance during the semester was measured by using their results at the midterm and their final mark at the course. The students' mean mathematical performance (scale 0-100) at the midterm test was 66.37 (SD=24.73) and their final performance based on their final mark (scale 0-100) was 68.73 (SD=23.91). Obviously, the correlation of the midterm test performance with the final mark was extremely high ($r=0.980$, $p<0.01$). Students with low performance at the initial mathematical test used by the study had a mean performance of 56 as mark at the midterm test and 58 at the final mark. The mean performance of the students with medium initial performance, at the midterm test was 64 and at the final mark was 65, while the mean performance of the students with high initial performance was 73 at the midterm test and 76 at the final mark. Those results indicated that the initial mathematical performance is a vital factor that influences engineering students' performance at the mathematical courses during their studies.

In order to examine the interrelations of students' mathematical performance with their attitudes towards Mathematics and beliefs about mathematics we have divided the sample into two groups based on their final mark at the university mathematics course AMAT111. 24 students with performance lower than the average and 26 students with higher. Students with higher performance had a more formalistic perception about the nature of mathematics (mean=3.85) in comparison to those with lower performance (mean=3.73). At the same time, they did not believe in the relation of mathematical concepts with the everyday life (3.29 in comparison to 3.78 of students with low performance).

DISCUSSION & CONCLUSIONS

The research on the domain of mathematics education and engineering education indicates that the engineering students face difficulties to attend mathematical courses during the first semesters of their studies at the engineering programs and many times those barriers are adequate to lead them to decide not to continue their studies. It seems that they are not ready to struggle against those difficulties due probably to their initial lack of knowledge about the central role of mathematics at their engineering studies and their tendency not indicating resilience on handling difficult situations. The present study examined the interrelations of the first-year engineering students' beliefs about the nature of mathematics and the learning processes of mathematics, their own self-efficacy beliefs about mathematics and the attitudes towards mathematics with their previous mathematical performance, derived by the high school education, and their performance during the attendance of an introductory course at the starting point of their engineering studies. The starting point was the need to identify the learning difficulties students face and the teaching barriers that academic of mathematics encounter in order to be able to propose suggestions and practical implications.

Results indicated that there was a high correlation between students' performance at the initial mathematical test and their previous mathematical performance at the high school. Additionally, results revealed the students' formalistic perspective of mathematics, which concentrated on using symbols, rules and procedures and their inability to relate the mathematical knowledge directly with problem solving situations in the field of engineering. Their previous school experiences seemed to be responsible for their negative attitudes towards mathematics and the low self-efficacy beliefs about their abilities to succeed in mathematics, although a further qualitative analysis of students' inner thinking will enable us to interpret those findings. It seems that their initial mathematical performance acts as the predominant predictor of their performance on the mathematics courses either at the beginning or the end of the university introductory course. It seems that even any positive experiences during the introductory course were not adequate to change their beliefs and attitudes.

The present study indicated that students' difficulties in learning mathematics at higher education may also be related to how mathematics is taught in high school education and the emphasis, which was given on procedural understanding and formalization without the respective conceptual understanding. The respective emphasis on formal symbolic mathematical language at higher education affects their ability to communicate mathematically (Nortvedt & Siqveland, 2018) and try to solve tasks by using any type of diagrams or representations. First-year engineering students' low self-efficacy beliefs can change through experiences of success in mathematics, which is not easy to be part of the engineering mathematics courses. Probably supplementary courses need to be attended before the attendance of obligatory courses and there need to be based on their previous acquired knowledge in order to secure the presence of at least few positive experiences. At the same time, applicants to engineering programs need to be aware of how mathematically demanding their course will be and they need to have accurate self-image about their strengths and limitations. If they choose to study at those courses, they need to have the appropriate support in order to face, struggle against and overcome their difficulties through acquiring the necessary knowledge and develop the basic learning strategies, such as the autonomy on learning. Guedet et al. (2016) argue that students are insufficiently prepared for the autonomy that is expected of them in higher education.

Results indicated that the participants' initial mathematical performance was low and below the expectations of attending a university course. This is a reality, which many times has to be faced by the academics and they have to recognize the students' difficulties in order to develop relevant content and to use effective teaching methods. At the level of higher education, we have to realize that there is not any profit by indicating the deficiencies of the high school education, we have to think creatively on how we can develop supplementary courses in order to fill the gap with the prerequisite mathematical knowledge and skills or we have to think critically and creatively on how to enrich the courses with inquiry-based processes, which will give emphasis on conceptual knowledge and problem-solving situations. The role of the academic teacher is extremely demanding as they are asked to follow pedagogical processes with which probably they are not familiar, and they do not have relevant experiences. We have to take into consideration that academic teachers at the level of higher education have not any intensive pedagogical knowledge about the use of inquiry-based and project-based processes, or assessment methods, which are relevant to different learning styles, or how to include the new knowledge into real-life context, interdisciplinary to the other courses. The present study did not examine this interesting dimension, which could be the central point of examination at a following up phase of the study.

The results of the study revealed an unexpectable inconsistency between students' self-efficacy beliefs and performance for a group of students. The low self-efficacy beliefs of students with high performance need to be examined further in order to be able to interpret their behavior. Probably although those students belong to the group with the highest performance during the present study, their previous experiences posed them at the group of students with low or medium self-image about their mathematical abilities, which was consistent with their low or medium performance in comparison to other people at the years of high school education. During the adult life the person's self-image does not change quickly if there are strong previous experiences or continuous experiences, which stable attitudes towards a domain.

Undoubtedly higher education should provide students with the opportunity to tackle the current and future professional challenges in order to solve new problems (Maron, 2016) and to produce new knowledge with or without the use of technology (Demostheouns et al., 2020). This is the main role of the higher education. The present study confirmed that the transfer of mathematics to the context of engineering seems to be problematic (Diane et al., 2015). The academics of mathematics who offer courses for engineering students need to contextualize mathematics with reference to engineering, mainly in cooperation with the engineering academics. By isolating mathematics, academics find it difficult to relate them with the different engineering branches and students are not able to see mathematics at an implemented or interdisciplinary context. There is a danger when mathematics becomes isolated from its use in engineering, as the initial perception of its value will be lost. Our findings confirm that engineering courses in higher education need to include discipline–appropriate engineering examples within at least mathematics (Diane et al., 2015). The formalistic perspective of mathematics with emphasis on symbols, rules and formal structure is the dominant belief after the high school education, which cannot be enhanced through the mathematics courses at the level of higher education. Emphasis has to be transferred on reasoning strategies and on conceptual understanding of mathematical concepts. Goold (2014) indicated that students at engineering courses feel uncomfortable with the ambiguity of an investigative approach, they prefer the certainty of following rules as part of the procedural knowledge, in order to achieve the answer, rather than any conceptual understanding of the mathematical notions. However, in this case we maintain a previous problematic situation.

In education, primary, secondary or higher, there are not any "magic wands", which can be used in order to face the difficulties and we cannot teach students who are characterized by interindividual differences through a common way. The present study is the first part of a project about the teaching of mathematics at engineering courses. It started by identifying the situation at the beginning and the end of a specific introductory mathematics course (AMAT111). By having in mind, the first-year students' beliefs, self-efficacy beliefs, attitudes and performance we have to continue by investigating the accountability of any innovative teaching methods, different assessment methods, teaching tools, self-regulatory strategies and teachers' training in order to face the difficulties, which had been identified. A future study could insist more on students' way of thinking by using semi-structure interview during the solving of difficult mathematical tasks. The main characteristics of the educational outcomes at the university level have to be the development of students' lifelong learning abilities, the understanding of the knowledge, the implementation of the knowledge into new situations, the analysis of the facts, the evaluation of the situations, the synthesis of the data in order to produce new knowledge. In the case of engineering studies, the mathematical knowledge and skills are necessary tools for the fulfilment of those goals, and we have to work towards this aim.

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