Enhancing Student Success in Engineering Programs through the Innovative Teaching Model

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Abstract **– The paper describes the research aimed at increasing the success rate of technical university students through a mathematics teaching model which uses digital technologies and emphasises the development of selected cross-cutting competencies.**

The innovative teaching model, whose impact was first verified in Mathematics I, offered in the first-year winter semester of bachelor's studies in 2022/2023, has yielded significant results. This paper presents the second part of the ongoing research, where the model's influence on students' Mathematics II and Physics success in the 2nd semester, was closely monitored. The findings, which indicate a statistically significant effect on students' achievements in Physics, underscore the importance of this research. Based on these results, the innovative model was further modified, extending it with recommendations for the broader application of math software in mathematics teaching and strategies to increase the success rate of women in technical universities. The extended model of teaching mathematics was then applied to teaching Mathematics I in the academic year 2023/2024, with a natural pedagogical experiment confirming its didactic effectiveness.

Keywords **– STEM, teaching model, digital technologies, students´ success rate.**

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1. Introduction

Since mathematics is a fundamental component of STEM and serves as a prerequisite for mastering the other STEM fields [1], the work of research community primarily aims to reduce student dropout rates, which pose a significant issue.

One of the possibilities to lower the dropout rate is by increasing the success rate of students in mathematics and subsequent subjects taught at the technical university. One possible way is to promote interest in studying mathematics subjects [2], [3], [4] by using digital technologies.

For the teaching model, a key criterion for an effective design is that it should foster the development of skills in using digital technologies to solve mathematical problems, as well as cultivate mental frameworks that enhance a conceptual understanding of mathematics. Motivating students to study mathematics is crucial because it provides the foundational knowledge necessary for advanced technical subjects. This includes developing digital literacy, mathematical competence, essential skills in science and technology, and the ability to engage in lifelong learning.

The educational framework includes mathematical practices and components from the pedagogical map developed by Pierce and Stacey [5]. The pedagogical map, through its analysis of the educational context's relevance, has evolved into taxonomy for effectively utilizing mathematical software in teaching. This includes tools like algebraic software, graphing calculators, geometry applications, statistical packages, and more [6].

Digital technology must be embedded in a consistent educational context in which working with technology is integrated naturally. One of the possibilities is to support improving of transferable competencies, which makes it possible to be flexible in the labour market. Therefore, introducing innovative models in teaching mathematical subjects is essential. It is essential to enhance graduate quality and lower dropout rates, particularly at technical universities.

To address this pressing issue, the development of a teaching model with maximum didactic effectiveness became the primary focus.

The quality of mathematics teaching largely determines the competence of future engineers [7], [8], [9]. The goal of teaching mathematics at a technical university should be to build a solid foundation in line with the curriculum requirements, foster an intuitive understanding of mathematics, and develop skills in mathematically modeling problems specific to the chosen field of study [10]. An essential feature of engineers when creating mathematical models is their ability to solve non-standard issues. Thus, the inability to solve them is why university students struggle to study mathematics for engineers.

Mathematics is essential to the education of engineers. However, as Daugherty [11] points out, mutual reciprocity between mathematics and the subjects of engineering training is essential. Engineers use the mathematical apparatus at work, from data analysis to creating complex models. On the other hand, demonstrating the use of the mathematical apparatus in specific conditions for solving engineering problems facilitates students' understanding of mathematics. From this fact follows the need for a close integration of mathematics and professional disciplines in the training of future engineers. How both areas of disciplines (mathematics and professional disciplines) are taught affects the level of understanding among students. The key is the authenticity of the solved tasks. Its level depends on the level of communication between mathematics and professional disciplines. As Merrill and Comerford showed [12], an integrated approach supports more deeply and multidimensional understanding of problems that are being solved. This, in turn, enhances the quality of their education.

The findings of Firouzian *et al.* [8] also support this fact. They state in their study that, in anonymous questionnaires, engineering students recommended improving mathematics teaching by extensively using software to solve mathematical problems, increasing practical exercises and solving practical problems on tasks from applied disciplines for easier understanding of mathematical concepts. In another study [13], students even more explicitly demanded to increase the relevance of mathematics content to the needs of their future professional practice and the necessity to tailor the content to the needs of further study in the field. Plank [14] experimentally demonstrated on a sample of more than 1000 students that the success rate of mathematics students in engineering studies was higher if specialised departments also participated in creating the curriculum. Research findings [15] also suggest that students struggle to identify the relationship between "real-life situations" and their "mathematical representation."

As stated by Tosmur-Bayazit and Ubuz [16], teaching mathematics without referencing real engineering problems (context) leads to creating simple mathematical models, which causes thinking only in predetermined structures. To educate more qualified engineers in formulating a mathematical model of a given physical state, interpreting its solution and refining the model, it is necessary to teach mathematics professionally, and students should know why and when a mathematical idea is relevant to their field. This can be achieved by selecting mathematical examples relevant to engineering disciplines and incorporating them into the learning content.

Suppose it is accepted that mathematics confers a certain intellectual status on its bearer. In that case, it can serve as a sieve to separate the successful from the unsuccessful candidates. Mathematics at engineering-oriented universities often has this character. Many students perceive subjects defined in this way as detached from "real" practice and may reject their content. In that case, they serve more to regulate the number of students than to train future engineers. Mathematics runs the risk of alienating students by being perceived either as overly demanding (acting like a sieve) or as disconnected from practical needs due to the emphasis on its inherent importance. As stated by Winkelman [17], those with mathematical talent can continue preparing for an engineering profession. Those who do not have this talent are viewed with distrust. Their ability to design creative engineering solutions is not considered much.

These findings, in line with the experience, underscore the importance of adopting a holistic approach when designing a mathematics curriculum for engineering studies. This approach fully utilises the potential for mutual enrichment of teaching both professional subjects and mathematics. Moreover, this approach is facilitated by the use of ICT.

Bringslid [18] suggests that enhancing the understanding of mathematics through interactive web-based documents could counteract the negative trends and issues related to girls' interest in engineering and mathematics. Gender differences in mathematics interest teachers who are committed to preparing all students equitably and responsibly for their future. The stereotype that persists is that women lack mathematical skills, achieve lower results in mathematical subjects, and lack sufficient experience with digital technologies. Evidence shows that in recent decades, the gap between women and men in mathematics performance has narrowed but has not yet been eliminated [19].

At the largest Slovak technical university, as a rule, only a third of women study in all three degrees of study every year.

Research has shown that teachers tend to exhibit explicit and implicit biases that can discourage girls from studying STEM [20]. Targeted research has pointed to concrete forms in which gender stereotypes are already manifested in teaching at primary and secondary schools [21].

In teaching circles, there is a prevailing myth that boys have better prerequisites for mathematics and girls for languages [22]. However, according to psychologist David Fontana [23], differences in the mathematical and language performance of boys and girls can be explained by the influence of the environment and have no biological basis. Nevertheless, mathematics and natural sciences have a "masculine" image, while humanities have fallen to girls.

Integrating digital technologies into mathematics education raises many questions. One of the most important questions is: What is the potential of digital technologies in education, and how can this potential be used most effectively in mathematics education? Drijvers [24] cites the National Mathematics Teachers Council, which argues that “digital technology is a crucial tool for learning mathematics in the 21st century, and therefore, all educational institutions must guarantee that their students have access to it.”

Understanding the use of digital technologies in teaching mathematics is constantly evolving, with a wealth of experience now available [25]. The dynamic directions in which research in this area progresses can be discerned from the published papers [5], [11], [26], [27]. Earlier works that mirrored an optimistic view have given way to studies that more realistically reflect the intricate relationships between students' thinking, the use of digital technologies, and traditional forms of learning [9], [27], [28], [29]. Digital technology can help students understand mathematics by providing more information and practical examples [9], [25]. By better understanding mathematics, students can also improve in technical subjects [30]. Various teaching models implemented at universities can alter the perceptions of both students and instructors towards mathematics courses and influence many teachers' classroom methodologies [31].

In this segment of the ongoing research, the focus was on assessing the impact of the mathematics teaching model on students' achievement in science courses within technical studies. The ambition is also to increase the proportion of women studying at a technical university by reducing their attrition during the studies. One possibility is to improve the success rate of women in mathematics and science subjects, as failure is a frequent cause of dropout. The paper also focuses on findings about the impact of the developed mathematics teaching model on students' performance in subjects that are part of engineering study programs.

2. Models Description

The teaching model outlined in [33] and implemented in Mathematics I during the 2022/2023 academic year (referred to as the innovative model), was developed to cultivate transversal competencies in students. These competencies encompass skills and knowledge that are not subject-specific but are applicable across multiple disciplines. The instructional design differs from traditional teaching in terms of content, methods and forms.

A key distinction between teaching with the innovative model and traditional methods is the emphasis on cultivating creativity, particularly flexibility and the ability to transcend functional fixedness. This is achieved, among other strategies, through the practice of variable labeling. Students that were taught experimentally, designate dependent and independent variables not only with the conventional symbols y and x but also with variable labels commonly used in mechanics, physics, automation, and other subjects relevant to their studies. This procedure is further described with examples from pedagogical practice due to its significant impact on success in the natural science subject of Physics. The approach was based on the observation that students who have no difficulty with calculations, such as $\int 2\, dx$. have a problem determining when calculating the physical task $\int p\, dV$. The research results indicate that students taught using the experimental approach more effectively apply their mathematical knowledge to other technical and natural science disciplines. To illustrate, a several concrete examples are presented. If students are to calculate the derivative of a function of the variable x, e.g., $f(x) = 5\, lnx$, eighty-five percent immediately determine the correct result: $\frac{df(x)}{dx} = \frac{5}{x}$. The task - to calculate $\frac{df(V)}{dV}$, where V is volume, T is temperature and R is a constant e.g., $f(V) = R\, T\, lnV$, no longer has such a high success rate. Correct result $\frac{df(V)}{dV} = \frac{R\,T}{V}$ was determined by less than fifty percent of the students. A similar situation is to tasks from the thematic unit of the function. Most students will sketch the graph of the function $y = \frac{1}{2}x^2 + 5$ correctly; however, if they are to sketch the dependence of the paths on time t, where $s(t) = s_0 + \frac{1}{2}\, t^2$, many students hesitate.

The innovative teaching model, which emphasizes the development of selected cross-sectional competencies, was extended (it will be referred to as the extended model) to include interactive internet applications suitable for individual content parts of mathematics.

This step was preceded by a thorough analysis of the mathematical software in terms of the included mathematical content, the difficulty of control, the consistency of the calculations and the availability of user support. Based on the results of the analysis, for each topic of the content of Mathematics I, a list of recommended software was assigned and sorted according to suitability for practicing the subject matter. The extension of the innovative model for intensive use of math software was implemented through methodological materials. These materials were designed to make it easier for students to work with the software and give them a reason to use it effectively. They are filled with engaging, practical examples of how mathematical applications can be used to solve problems, making the learning experience more practical and relatable. The methodological materials also contain warnings to students about the potential pitfalls of calculations or displaying graphs of functions, ensuring they stay on the right track.

Additionally, they provide recommendations for using the software to solve tasks and check the correctness of the solution, further enhancing their practical understanding of the software. Mathematical software made routine calculations easier for students and eliminated numerical errors. It allowed checking the solution of tasks and a graphical display of solutions. Using math software and appropriate applets helped deepen the understanding of the subject matter. The advantage was using various types of math software, which contributed to training students' flexibility.

The innovative model was also expanded with strategies to increase women's self-confidence in solving mathematical problems. Increasing women's confidence in solving mathematical problems is essential and can be achieved through several methods:

- Strengthening education and skills. Providing access to a wide range of educational resources - including online courses, tutoring programs, comprehensive study materials such as detailed lecture presentations, solved and unsolved problems, instructions for effective use of mathematical software, and interactive self-tests - empowers women to build greater confidence in their abilities. This was implemented in the information system of the subject Mathematics I.
- Mentoring and role models. The presence of successful women in mathematics and related fields is not just a source of support but a beacon of inspiration. Their achievements can instill hope and motivation, inspiring confidence in women that they, too, can excel in these fields. This fact was presented through the teachers of the Mathematics I subject since they are all women.
- Practical experience and frequent practice. The more women are involved in solving mathematical problems and gaining practical experience, the more competent and confident they feel. This hands-on approach is not just a method but a proven method for increasing confidence in solving mathematical problems. In this context, mathematics teachers often provided women with more opportunities to present solutions to assigned tasks during exercises, aiming to strengthen their self-confidence. This theoretical and practical approach allows women to see their skills in action and build their confidence through real-world application.
- Support for troubleshooting. It is important to teach women how to systematically and creatively approach solving problems and not be afraid of mistakes or failures because a lot can be learned from that, too. Support for problem-solving was implemented by encouraging students to solve tasks independently. The teacher focused on more frequent consultations during the solution process, even if the women did not request a consultation. He motivated them to look at problems as opportunities to learn new things; in case of mistakes, he explained that this is a natural part of learning.
- Eliminating the fear of mathematics. Reducing the fear of mathematics increases academic achievement in math significantly [32]. Use of math software in various parts of the teaching process also contributed to reducing the fear of mathematics. Students can use the help of software to solve some tasks that are difficult for them. For example, when calculating the area content or volume of rotating bodies, it is necessary to outline the curves that delimit the given elementary area. Many students were afraid of this part of the solution. However, their concerns disappeared with the possibility of using math software in this part of the solution.

Organizationally, the use of the mentioned methods was ensured by a seminar for teachers of Mathematics I before the beginning of the winter semester 2023/2024 and the elaboration of the extension of methodological material, which serves as an aid for a uniform approach to teaching Mathematics I since four teachers taught the subject.

3. Research Questions

The innovative model was first applied in teaching Mathematics I in the winter semester of 2022/2023, confirming its didactic effectiveness [33]. Given that, the main goal was to reduce student dropout, hence, it was necessary to determine whether using an innovative model also impacted the following study subjects, not just directly on the subject where it is used.

Therefore, in the same academic year's summer semester, the impact of the innovative model on students' success in Mathematics II and Physics was observed. These observations were part of natural pedagogical experiments, crucially designed to find answers to the following pivotal research questions.

- Does applying the innovative teaching model in Mathematics I significantly improve the average achievement of the experimental set, which was taught using the innovative model, compared to the control set, which was taught using traditional methods in the following subjects: Mathematics II or Physics, which were taught in traditional ways? This comparison is essential for understanding the impact of the innovative model on subsequent subjects.

The study goes beyond just comparing the mean achievement of the experimental and control sets. A step further was taken to conduct a gender-based analysis, ensuring that the innovative teaching model is effective for all students, regardless of gender. This inclusive approach is crucial to this study, demonstrating the commitment to equitable education. The second research question covers this.

- Is there a statistically significant difference in the average achievement between the experimental and control sets for both male and female students?

The gender-oriented analysis, a pivotal part of the study, is about more than just extending the model. It is about urgently addressing the gender disparities that exist in technical universities. The innovative teaching model is a step towards ensuring academic success for all students, regardless of gender, with a specific aim of improving the representation of women at technical universities.

During the holidays, the innovative teaching model was extended to include even more digital technologies and strategies to increase women's confidence in solving mathematical problems. Implementing these strategies can significantly increase women's self-confidence in mathematics and encourage them to pursue further education in technical fields. Since the proportion of men studying in technical study programs is still higher than that of women, it is necessary to reduce the decrease of women, especially in the first semesters of technical studies.

In the previous academic year, the implementation of this innovative teaching model did not result in a statistically significant difference in the average success rates between men and women in Mathematics I [54]. Therefore, there is a desire to be aware if the extension of the innovative model changed the results.

Therefore, the following research question to guide the investigation were formulated:

- Does a statistically significant difference exist in the average success rates between male and female participants across the entire respondent set?

4. Methodology

Based on the above research questions, the following working hypotheses were established:

H1: The implementation of the instructional design has a significant impact on students' performance in the Math II course.

H1a: The application of the instructional design significantly influences students' achievement in Math II on the 1st exam date.

H1b: The implementation of the instructional design has a significant impact on students' performance in Math II during the 2nd examination date.

H1c: The implementation of the instructional design has a significant impact on 1st and 2nd-term exam results, as well as the overall performance of male students in Math II. Males in the experimental set outperformed those in the control set in this subject.

H1d: The implementation of the instructional design has a significant impact on the accomplishment of female students in Math II on the 1st and 2nd exam dates, as well as on their overall performance. This indicates that women in the experimental set performed better in the subject than those in the control set.

H2: The implementation of the innovative design has a significant impact on students' achievement in Physics.

H2a: The implementation of the innovative design significantly influences students' performance in the 1st term examination in Physics.

H2b: The implementation of the innovative design has a significant impact on students' achievement in the 2nd term Physics examination.

H2c: The implementation of the innovative design has a significant impact on the pass rates of male students in Physics for both the 1st and 2nd term exams, as well as their overall pass rates. Males in the experimental set performed better than those in the control set.

H2d: The implementation of the innovative design has a significant impact on the achievement of female students in Physics, both on the 1st and 2nd examination dates, as well as their overall success rate. Female students in the experimental set outperformed those in the control set.

Table 1. Success rate in math II

	Set	N	M	SD	SE M
Overall	C	109	2.49	2.02	0.19
	E	124	2.02	1.79	0.16
First attemp	C	109	1.98	2.08	0.20
	E	124	1.62	1.77	0.16
Second attemp	C	44	1. 64	1.10	0.17
	E	52	1.27	1.03	0.14

H3: After implementing the extended teaching model in Mathematics I, a significant difference was observed in the average achievement between male and female respondents in the entire set.

Data were collected using the assessment marks after the end of the appropriate semester following the curricula for each subject for all sets. The results were analysed using Minitab statistical software. A two-sample T-test was used to verify hypotheses.

The respondent sets investigated in the research, which focused on the influence of innovative model in subsequent subjects, consisted of 233 students in Math II and 265 students in Physics I.

Math I was studied by 211 students of all study programs at the faculty. At the beginning of each academic year, the study department divides students into two lecture sets and several exercise groups. The experimental group was selected based on the willingness of teachers to implement experimental teaching methods, as the study was conducted as a natural pedagogical experiment.

As a result of the natural pedagogical experiment, the number of students in Math II and Physics in the 2nd semester was higher than that in Math I in the 1st semester. This increase was due to students repeating the subjects. Since the innovative model was first introduced in 2021/2022 as a pilot run with the same division of lecture groups, it is reasonable to assume that the research results were not influenced by repeating students.

In the second part of the research, the researchers sought to answer whether there is a significant difference in the achievement of males and females after applying the extended model. The respondent set consisted of 305 students enrolled in the course Math I in the 2023/2024 academic year.

5. Results and Discussion

This section presents the results and their discussion for Mathematics II, Physics, and Mathematics I after applying the extended model.

The first two sections present the results separately for the male and female groups. The third section compares the results for males and females.

5.1. Results in Math II

Table 1 reveals that the overall pass rate of students in the experimental set (2.02) for the Math II exam is 0.47, lower than that of students in the control set (2.49). But, a T-test for independent samples conducted using Minitab software indicated that this difference is not significant ($p=0.067$), as $p > 0.05$. The results were similar for the first exam attempt, where the performance of control set students (1.98) was 0.36 higher than that of the experimental set students (1.62). However, this difference was not significant ($p=0.159$). A similar pattern was observed in the second exam attempt, with control set students achieving a higher average pass rate (1.64) compared to the experimental set (1.27). Again, the difference in achievement was not significant ($p=0.097$).

Considering the results above, hypotheses 1, 1a and 1b were not confirmed. The research results did not support the above hypotheses for several reasons. One of them is that students use only the customary variable labelling in the Math II course: The y-label for dependent variables and the x-label for independent variables. Overcoming the stereotype and functional focus on x and y was one of the essential parts of the model. Another possible explanation is that the control group included students from AI and Mechatronics, which are more closely aligned with mathematics, whereas the experimental set comprised students from fields such as Personnel Work and Industrial Management.

5.2. Results for Set of Men and Women in Math II

The results for the male set are consistent with those observed for the entire respondent set. As shown in Table 2, the overall achievement of male participants in the experimental set (1.94) was lower than that of male participants in the control set (2.28). However, a T-test indicated that this difference was not significant ($p=0.204$). A similar trend was observed for the achievement on the 1st attempt, where males in the experimental set completed the Math II course with a lower average score (1.58) compared to the control set (1.75). Again, the difference in mean achievement was not significant ($p = 0.546$). On the 2nd attempt, males in the experimental set achieved a lower achievement (1.30) than those in the control set (1.63). This difference was also not significant, as confirmed by a T-test ($p = 0.179$). These findings do not support Hypothesis 1c, which proposed that the innovative teaching model would have a significant impact on the achievement of the male group in Math II.

The reasons for this outcome are likely similar to those discussed in the previous section for the entire respondent set.

The results for the women’s group were unexpected (Table 3). The overall performance of the experimental set (2.32) was lower than that of the control set (3.86). This difference was significant (p = 0.027). Similar findings were observed for the 1st exam attempt, where the performance of women in the experimental set (1.75) was lower than that of the control set (3.57), with the difference being statistically significant (p=0.018). The research did not support Hypothesis 1d, which proposed that the innovative teaching model would have a statistically significant effect on achievement in the women’s group.

Table 2. Men´s success rate

	Set	N	M	SD	SE M
Overall	C	95	2.28	1.93	0.20
	E	96	1.94	1.82	0.19
First attemp	C	95	1.75	1.95	0.20
	E	96	1.58	1.80	0.18
Second attemp	C	41	1.63	1.11	0.17
	E	37	1.30	1.08	0.18

It is believed that the women's lack of interest in mathematics in the experimental set was fully manifested, negatively impacting their results not only in Mathematics I [33] but also in the subsequent subject, Mathematics II. On the contrary, women from the control set who study in programmes such as Applied Informatics and Mechatronics seem to have a more positive attitude towards mathematics and higher confidence in solving mathematical problems and excellent knowledge, which is reflected in their success rate.

Table 3. Women´s success rate

	Set	N	M	SD	SE M
Overall	C	14	3.86	2.11	0.56
	E	28	2.32	1.68	0.32
First attemp	C	14	3.57	2.34	0.63
	E	28	1.75	1.71	0.32
Second attemp	C	3	1.67	1.15	0.67
	E	15	1.2	0.941	0.24

5.3. Results in Physics

Following the negative results in Mathematics II, it was encouraging to observe that, on the first attempt at Physics, the mean achievement of the experimental set was significantly higher than that of the control set (p = 0.027).

As seen from Table 4, the students in the experimental set achieved higher mean results than those in the control set. The results were consistent on the 2nd attempt of the Physics exam, where students in the experimental set again achieved a higher achievement than those in the control set. A T-test confirmed that this difference was significant (p = 0.016).

Table 4. Success rate in physics

	Set	N	M	SD	SE M
Overall	Con.	97	1.87	1.13	0.12
	Exp.	168	2.042	0.898	0.069
First attemp	Con.	97	1.43	1.12	0.11
	Exp.	168	1.738	0.992	0.077
Second attemp	Con.	72	1.292	0.516	0.061
	E	70	1.529	0.631	0.075

Hypotheses 2a and 2b were confirmed, supporting the prediction that implementing the teaching model would have a statistically significant impact on students' performance in both the first and second attempts of the physics exam.

Table 4 shows that, achievement of the experimental set students in the Physics exam (2.42) was higher than that of the control set (1.87). But, T-test for independent samples conducted using Minitab software showed that this difference wasn't significant (p = 0.193), as p > 0.05. Thus, Hypothesis 2 was not confirmed.

One possible explanation may be that the difference between the experimental and control set success rates was no longer statistically significant on the third attempt at the physics exam, which students usually take with no science talent. That fact may have influenced the overall result. In the future, it will be necessary to design a modification of the innovative model so that the students with the lowest science talent will also benefit more from the teaching model.

5.4. Results for Set of Men and Women in Physics

Hypothesis 2c was confirmed. Implementing the instructional design have a significant impact on the achievement of male students in Physics, both on the 1st and 2nd attempts, as well as on their overall success rate.

As can be seen from the table (Table 5), the men in the experimental set reached a higher overall mean achievement (2.023) than the men in the control set (1.65). The difference was significant (p = 0.003). The same results were also recorded at the first attempt of the Physics subject examination, where the experimental set students achieved an average pass rate of 1.667 and the control set students only 1.238.

A two-sample T-test confirmed the statistical significance of the difference in mean achievement (p = 0.001). On the second attempt, the results were analogous. The average success rate in the experimental set was 1.574, and in the control set - was 1.292. The difference was also significant (p = 0.008). The above results show that the effect of practicing overcoming the functional focus on labelling variables x and y and the impact of solving non-specific transfer tasks, which formed a substantial part of the innovative model, were fully evident in the male group in the Physics subject.

Table 5. Men´s success rate in Physics

	Set	N	M	SD	SE M
Overall	C	80	1.650	0.858	0.096
	E	129	2.023	0.888	0.078
First attemp	C	80	1.238	0.799	0.089
	E	129	1.667	0.979	0.086
Second attemp	C	65	1.292	0.522	0.065
	E	61	1.574	0.644	0.083

A completely different outcome was unexpectedly observed in the women's group. Women in the control set reached a higher achievement (2.88) compared to those in the experimental set (2.103), but the difference was not significant. Similar results were observed in the first attempt at the Physics exam, where women in the control set had a higher achievement (2.35) compared to women in the experimental set (1.97); however, this difference was not significant (p=0.426). The same pattern emerged in the 2nd attempt, with women in the control set achieving an average pass rate of 1.286 compared to 1.222 for women in the experimental set. Due to the limited data, a statistical test was not applied for this attempt (Table 6). These findings did not support Hypothesis 2d, which proposed that the implementation of the instructional model would have a statistically significant effect on success rates for the 1st and 2nd attempts and the overall success rate of women in Physics.

Again, the results obtained may be due to the predominance of interest and knowledge of the women in the control set over the intervention in the form of the teaching model. The results showed that to positively influence women's outcomes, the teaching model needs to be modified appropriately.

Table 6. Women´s success rate in Physics

	Set	N	M	SD	SE M
Overall	C	17	2.88	1.65	0.40
	E	39	2.103	0.940	0.15
First attemp	C	17	2.35	1.80	0.44
	E	39	1.97	1.01	0.16
Second attemp	C	7	1.286	0.488	0.18
	E	9	1.222	0.441	0.15

5.5. Results for the Whole Set of Respondents After Applying the Extended Model in the Subject Mathematics I

Hypothesis 3 was confirmed. Significant differences exist in the average achievement of men and women after implementing the modified teaching model in Mathematics I. As shown in Table 7, women reached a higher overall achievement (3.14) compared to men (2.41), with the difference being significant (p = 0.023). A similar outcome was observed in the first exam attempt, where women had an average success rate of 2.94, while men averaged 1.90, and the difference was again significant (p=0.003). Due to insufficient data for the women's group, further attempts were not evaluated.

Table 7. The women´s and men´s success rate in Math I after applying the modified teaching model

	Set	N	M	SD	SE
Overall	M.	269	2.41	1.50	0.092
	W.	36	3.14	1.78	0.30
First attemp	M.	269	1.90	1.52	0.093
	W.	36	2.94	1.90	0.16
Second attemp	M.	109	1.99	1.17	0.11
	W.	6	2.00	1.10	0.45

The stated findings for the set of respondents regarding the unequal overall achievement of males and females in the subject Math I disagree with the results of previous research [33] and other researchers results of Ajai and Imoko [34] and Tsui [35], where there were no significant differences in the performance of men and women in mathematics. They partially agree with the findings of a comparative study of the results of distance learners in mathematics.

There were significant differences between men and women in each of the three grades. However, men were more successful here [36].

Another form of teaching could have influenced the results of the comparative study. Authors in [37] show that females are more comfortable with face-to-face teaching than distance learning. Based on the mentioned facts, it can be assumed that the intervention in the form of an extended model caused significant differences in the performances of men and women in Mathematics. Further research will be needed to verify this assumption.

6. Conclusion

The teaching model demonstrated a positive influence on student performance. The research confirmed that the integration of digital technologies and an emphasis on cross-disciplinary competencies in mathematics education positively affected student success in science subjects, particularly Physics.

The model had a statistically significant impact on student success in the first and second attempts at the Physics exam, validating Hypotheses 2a and 2b. These results highlight the advantages of flexibility training and the inclusion of tasks aimed at non-specific transfer.

The findings revealed following gender-based differences in the model's effectiveness:

- Male students: Hypothesis 2c was confirmed, demonstrating a statistically significant improvement in the performance of male students across all attempts in Physics. This underscores the effectiveness of the teaching model in enhancing male students' outcomes.
- Female students: The model showed limited effectiveness for female students, as Hypothesis 2d was not confirmed. Female students in the control group, particularly those enrolled in Applied Informatics and Mechatronics programs, outperformed those in the experimental group. This suggests a need to adjust the model to strengthen women's confidence and foster a positive attitude toward mathematics.

Concerning subject-specific insights, for Mathematics II, Hypotheses 1, 1a, 1b, and 1c were not confirmed, indicating no significant differences between the experimental and control groups. This could be attributed to the absence of two essential elements of the model—overcoming stereotypes in variable labeling and emphasizing tasks aimed at non-specific transfer. Students in the control group, particularly women, exhibited more positive attitudes and greater confidence in mathematics, which contributed to their superior performance.

The extended teaching model, implemented in the 2023/2024 academic year, incorporated additional digital technologies and placed greater emphasis on cross-disciplinary competencies.

Preliminary findings validated Hypothesis 3, demonstrating significant improvements in the performance of both male and female students. This supports the premise that targeted training can benefit both genders.

The experimental results revealed the strengths and limitations of the proposed model. The strengths of the model include in particular:

- Improved Performance in Physics: The model significantly enhanced student success in Physics, particularly among male students.
- Development of Cross-Disciplinary Competencies: It fostered transferable skills across subjects, contributing to broader academic development.
- Foundation for Improvement: The findings provided valuable insights for refining and adapting the model for diverse student groups.

The following features currently limit the general effectiveness of the model:

- Limited impact on female students: The model was less effective for female students, indicating a need for gender-specific strategies to build their confidence and interest in mathematics.
- Minimal effect in Mathematics II: The teaching model did not significantly influence results in Mathematics II, partly due to the absence of key elements in its design for this subject.

The research findings also have several important implications for mathematics education. There exists need for gender-sensitive teaching approaches. The results underscore the need to design teaching models that address gender-specific attitudes and confidence levels, particularly in STEM fields. The results also showed that digital technologies must be integrated into the educational model. Positive outcomes in Physics suggest that digital tools can enhance learning outcomes when combined with a focus on core competencies. In the teaching of mathematics, as a basic discipline in STEM fields, it is necessary to focus also on transferable skills. Emphasizing cross-disciplinary skills can contribute to better performance in various academic areas.

The direction of further research will be focused on improving the teaching model. Future work should incorporate strategies to improve students' attitudes toward mathematics, with a focus on enhancing the confidence and engagement of female students. An examination of the impact on individual subjects will also be necessary. Further exploration is needed to understand why the model was less effective in Mathematics II and to adapt it for improved results in mathematical contexts. Long-term studies are also planned as part of the ongoing research work.

The intention is to carry out long-term research to evaluate the sustained impact of the teaching model on student performance across subjects and academic years.

Given the results achieved, it will be necessary to develop and test interventions aimed at fostering positive attitudes and self-confidence, particularly among female STEM students. The next academic year is planned to expand the application of the model. The intention is to test the expanded model to diverse contexts and disciplines to assess its universality and scalability.

Addressing these areas will enable future research to enhance the didactic effectiveness of innovative teaching models, contributing to higher success and retention rates in STEM programs.

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