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GENDER DIFFERENCES IN ACADEMIC PERFORMANCE OF FIRST-YEAR STUDENTS IN STEM DISCIPLINES

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Abstract. In the context of the ongoing development of STEM education and persistent discussions regarding gender inequality in academic achievement, the issue of identifying actual performance differences between male and female students remains highly relevant. This study focuses on examining gender-related differences in academic achievement among first-year university students enrolled in STEM programs.

The aim of the research is to identify and analyze differences in academic performance between male and female students across foundational STEM courses and to evaluate commonly held assumptions regarding male advantage in STEM disciplines. The study contributes to the academic discourse on gender equity in higher education by providing empirical evidence based on real academic data.

The scientific significance of this research lies in expanding the empirical knowledge base on gender differences in STEM education, while its practical significance is associated with the potential application of the findings in the development of inclusive educational policies and support strategies in higher education institutions.

Methodologically, the study is based on descriptive statistics and non-parametric statistical analysis. Archived and anonymized academic records of first-year students from 2021 to 2023 were analyzed using the Mann–Whitney U test. The dataset included student performance across five introductory STEM courses.

The results revealed that in four out of five courses, female students achieved statistically significantly higher average grades than male students. In the course on programming and algorithms, no statistically significant gender differences were identified. These findings challenge deeply rooted stereotypes regarding inherent male superiority in STEM fields and highlight the influence of sociocultural, psychological, and educational factors on academic achievement.

The value of this research lies in its contribution to promoting evidence-based approaches to gender equity in STEM education. The practical implications include informing the design of inclusive teaching practices and targeted academic support initiatives.

Keywords: gender disparities, STEM education, academic achievement, gender equity, quantitative analysis, inclusive pedagogy, educational policy, higher education

Introduction

The ever-growing problem of gender equity is now a primordial component of various reform initiatives within the field of education. As a means of moving ahead, the promotion of equity within the realm of STEM education (Science, Technology, Engineering, and Mathematics) by narrowing the existing gaps between men and women within this field is crucial. Such existing gaps not only impede the rapid advancements needed within the field of innovation, but they also directly or indirectly affect the design of the STEM learning curriculum or strategy [1]. Lessons of the past show that women are seriously underrepresented within industry as well as academia.

Studies on gender and performance in STEM education show controversial results. A male superiority in STEM education is reported by Van de Gaer et al. [2] and Tate [3], but this seems overemphasized, since the gender gap is gradually reduced or nearly similar in some cases by Hyde et al. [4] and Yücel & Koç [5]. It is clear that the gender itself might not actually affect students' performance but the educational methodologies might actually have significant implications.

Most contemporary discourses around gendered inequalities in STEM courses have framed gender stereotypes as obstacles to reaching equity. Problem-solving skills, mathematical reasoning, math anxiety, and self-efficacy have been cited as factors for differences observed among men and women [6].

The gender divide in science, technology, engineering, and mathematics education is a complex issue that depends not only on cultural and educational expectations and abilities of students, but also on students' educational experiences and instructional design [7]. While some studies argue that gender disparities exist in student engagement and career goals, some available evidence has indicated that cognitive abilities and skills in mathematics problem-solving and self-efficacy, and instructional design are interrelated and impact educational performance. The issue of a gender divide in science, technology, engineering, and mathematics is complex because it depends on a variety of interrelated factors. The structured design of courses and use of teaching and assessment methods appear significant in influencing educational performance, as indicated by previous studies and this study. Developing a fair and inclusive learning environment may help improve innovation and educational performance of all learners and help bridge the gap that exist in science, technology, engineering, and mathematics education.

There is a performance gap not only based on intelligence but also on approach to the problem and the manner through which they are taught. Research

has suggested that female learners do well in structured conceptual environments; thus, it has been demonstrated to perform better than male students and perform well in the courses which have logical and conceptual demands [8]. Even in developed countries where there is greater gender equality, gaps in attainment within STEM persist-a phenomenon known as the gender-equality paradox [9]. It would be societal norms and stereotypes that cause disparities in this manner. Pedagogically, it hence realizes the importance of inclusive course design, active instructional strategies, and mentoring programs to foster equitable participation. Permanent gaps not only impact students' sense of inclusion but also shape their educational and career trajectories-the potential to limit diversity and the competent workforce within the fields of STEM [10].

Developmental theory helps understand underlying reasons for gender disparities in STEM fields [11]. Even though girls perform better than boys in mathematics-related concepts in middle and secondary schools, taking up math-related areas remains underrepresented in more advanced nations, which clearly explains the paradox of gender equity [12]. The outcomes clearly reveal that, apart from aptitude, there is a significant underlying influence of course and teaching methodologies, and engagement in STEM areas at an initial level [13, 14]. Variation in modes of problem-solving, mathematical reasoning, and abilities in spatial areas is also shown to have an interaction effect with course methodologies, which underlines the importance of well-designed tasks, feedback, and variability in solving problems for equal performance [13, 14].

The complexity of gender differences in STEM is highlighted in this review, challenging overly simplistic theories and reflecting on the need for comprehensive responses. It is essential for future research to continue to explore how social norms, educational practices, and cognitive variables interact to affect gender differences in STEM. Reducing these differences requires educational intervention, and changing social constructions, which will help reduce biases and create a more equitable and welcoming environment for all those interested in STEM careers.

These studies highlight that gender differences in STEM education are not simply a potentiality but a collection of cognitive, psychological, sociocognitive and pedagogical challenges. The only way to address these challenges is by executing targeted interventions that promote equitable learning spaces while supporting diversity in the styles of learning.

This study examines if male and female students perform differently in university STEM courses. Through a quantitative analysis approach, anonymized student records from the 2021 to 2023 cohorts were analyzed to investigate disparities across five major STEM subjects. Statistical tests comparing the performance of male and female students provided evidence of gender-related

phenomena in STEM education, thereby contributing to the evidence-based discourse aimed at creating equitable learning spaces.

Research Questions:

To what extent do gender disparities exist in academic performance across five core STEM courses among first-year university students?

In which STEM subjects male and female scores differ considerably and in which subjects male and female scores do not differ significantly?

How can these findings inform pedagogical strategies and policies to promote gender equity in STEM education?

Materials and Methods

This study presents formal findings of a quantitative research project that investigates gender differences in STEM academic performance, using a sample of 448 male and 149 female first-year students from the 2021–2023 cohorts. It was conducted in a public university providing undergraduate studies in STEM fields in the traditional face-to-face education setting. The courses examined in this study (Discrete Mathematics, Mathematical Analysis I, Linear Algebra, Information-Communication Technologies, and Algorithmization and Programming) are obligatory for first-year students and consist of lectures and seminars. The grading scale is a 100-point system based on the written exam and continuous performance tasks according to the course design. Additionally, the study focused on examining anonymized student records of academic achievement, discipline, gender (and their combination), using a quantitative research design. Our use of Jamovi to complete our analysis also ensured that our evaluation process was transparent and complete. There were two statistics that calculated our analytic plan: two independent samples t-tests (for comparing mean grades) and descriptive statistics (for comparing variations in academic achievement). This process provided information on the extent and nature of academic differences related to gender, enabling us to determine the extent and nature of gender differences related to STEM education at the university.

Results and Discussion

To evaluate differences in academic achievement, descriptive statistics, Shapiro-Wilk Test for normality, Mann–Whitney U tests for non-parametric comparisons, and effect size estimates (rank-biserial correlations) were employed. The findings show some significant trends:

Descriptive Statistics

Descriptive statistics for two groups from five subjects, namely Linear Algebra, Discrete Mathematics, Algorithmization and Programming, Informational-Communicational Technologies, and Mathematical Analysis I, are shown in Table 1. Female students (in table indicated as 2) had higher mean

scores (μ_2) in every one of the subjects compared to the male students (in table indicated as 1), who had mean scores (μ_1).

Table 1. Descriptive data

	Gender	*ICT*	*Algorithmization and programming*	*Discrete mathematics*	*Mathematical analysis I*	*Linear Algebra*
Missing	1	0	0	0	0	0
	2	0	0	0	0	0
Mean	1	75.3	72.4	57.9	53.7	64.9
	2	79.3	73.8	67.6	68.6	73.9
Median	1	77.0	78.0	65.0	60.0	69.0
	2	82.0	77.0	71.0	70.0	79.0
SD	1	16.8	21.7	26.0	26.3	23.3
	2	14.7	17.9	18.8	18.2	20.9
Shapiro–Wilk W	1	0.828	0.869	0.827	0.920	0.851
	2	0.823	0.909	0.892	0.884	0.793
Shapiro–Wilk p	1	<.001	<.001	<.001	<.001	<.001
	2	<.001	<.001	<.001	<.001	<.001

Testing for Normality: Shapiro-Wilk Test

Prior to conducting the comparison analysis, the Shapiro-Wilk test was performed to check for normal distributions in the score distributions for each participant. The results of the test showed the data did not exhibit a normal distribution ($p < 0.05$ for most participants), necessitating a non-parametric test to complete the comparison analysis of the two independent groups, as the data did not follow a normal distribution.

Inferential Statistics: Mann-Whitney U Test

The Mann-Whitney U test was utilized in place of the independent samples t-test for violation of normality assumptions. In cases when data does not satisfy normality assumptions the Mann-Whitney U test can be performed in order to examine two independent groups. The results are shown in Table 2.

Table 2. Mann-Whitney U Test (two-tailed)

Course	*Statistic (U)*	*p-value*
Informational-communicational technologies	27863	0.002
Algorithmization and programming	33375	1.000
Discrete mathematics	26136	<.001
Mathematical analysis I	22040	<.001
Linear Algebra	23235	<.001

Note. Ha: $\mu 1 \neq \mu 2$.

The first analysis (two-tailed test, $H_a: \mu_1 \neq \mu_2$) concluded that there was evidence female students out-performed in a number of courses, including Informational-Communicational Technologies, Discrete Mathematics, Mathematical Analysis I, and Linear Algebra. Only in the course of Algorithmization and Programming was no evidence of significant differences.

The second analysis (one-tailed test, $H_a: \mu_1 < \mu_2$) confirmed that male students performed significantly worse than female students in the majority of subjects, as presented in Table 3.

Table 3. Mann-Whitney U Test (one-tailed)

Course	*Statistic (U)*	*p-value*
Informational-communicational technologies	27863	0.001
Algorithmization and programming	33375	0.500
Discrete mathematics	26136	<.001
Mathematical analysis I	22040	<.001
Linear Algebra	23235	<.001

Note. Ha: $\mu 1 < \mu 2$

Additional Analysis 1: Effect size by subject

Mann–Whitney U test results showed that female students had significantly higher academic achievement than male students in four of five STEM areas. Effect size estimates using the rank-biserial correlation showed small to moderate differences between groups. In fact, small effects were demonstrated in Informational – Communicational Technologies (U=27,863, p=.002, r = .17) and Discrete Mathematics (U=26,136, p<.001, r = .22), moderate effects were shown in Mathematical Analysis I (U=22,040, p<.001, r = .34) and Linear Algebra (U = 23,235, p < .001, r= .30). No significant differences were found in Algorithmization and Programming (U=33,375, p=1.000, r ≈.00). In total, these results indicate that female; first-year students achieved consistently higher academic outcomes than male students across most STEM disciplines with small to moderate effect sizes.

Additional Analysis 2: Impact of excluding failed students

In order to further verify the stability of the results, another analysis was run omitting failed students from the study, and again measuring gender differences on academic performance to assess whether students scoring sitting low influenced the trends.

The Mann-Whitney U test was run again on the comparison of male and female students' performance on the five different areas of STEM. The results were consistent with the above study presented in Table 4.

Table 4 - Mann-Whitney U Test for excluding failed students (one-tailed)

Course	*Statistic (U)*	*p-value*
Informational-communicational technologies	26977	0.002
Algorithmization and programming	31150	0.694
Discrete mathematics	24462	0.009
Mathematical analysis I	20348	<.001
Linear Algebra	20640	<.001

Note. Ha: $\mu 1 < \mu 2$

This additional validation strengthens the reliability of the study's findings and indicates that the performance gap in favor of female students in concept-heavy subjects persists, regardless of whether lower-performing students are included in the analysis. These results challenge traditional assumptions about gender and STEM proficiency, highlighting the influence of instructional methods, learning environments, and student engagement on academic outcomes.

The results of this particular study have managed to show that differences between genders regarding performance in STEM disciplines do not exist in an identical form, and they largely correspond to instructive features of specific disciplines. Female participants achieved better than male ones in Discrete Mathematics, Mathematical Analysis I, Linear Algebra, and Information-Communication Technologies, while there were no significant differences in Algorithmization and Programming.

One of the important aspects of the subjects with the largest gaps in gender differences is that they pay more attention to abstract thinking and symbolic expression. In fact, these subjects are delivered in lecture-oriented modes of instruction and assessed by high-stakes tests that privilege procedural correctness and symbolic manipulation. This can raise different levels of requirements in dealing with self-regulated learning, conceptual processing, and independent problem-solving tasks on the part of the learners.

Nevertheless, the lack of gender differences in Algorithmization and Programming might be linked to the organizational structure of the course. Indeed, the Programming course is typically conducted in the form of laboratory work and project activities with continuous formative assessment. Such an approach provides immediate feedback and allows for collaborative problem-solving activities and is acknowledged as being effective in eliminating performance gaps between genders.

Moreover, the findings indicate that the differences in the results may be not only due to the individual learning style, but also the manner in which the course is provided. This is particularly true in those conceptually challenging topics in which the lack of worked example, scaffolding, or guided practice may

lead to disparities in learning. Incorporation of such elements into the course may improve learning by reducing disparities.

Finally, the role that class room climate and support structures play in student achievement cannot be overstated. Teaching approaches which adopt a growth mindset, productive struggle, and decrease anxiety related to high-stakes testing might play an important role in closing the gender gap. Hence, the discourse related to the gender gap in performance, particularly in STEM subjects, needs to be framed not merely within the psychological paradigm, but additionally within the tangible pedagogical frameworks by which learning is implemented for first-year university students.

Conclusion

This research investigated gender differences in academic outcomes for five main STEM disciplines among freshmen university students; the study identified that such differences depend on the subject. The research discovered that female students show significantly better results in Discrete Mathematics, Mathematical Analysis I, Linear Algebra, and Information-Communication Technologies, while there are no significant differences between genders regarding Algorithmization and Programming outcomes.

Notably, the results reveal that differences in STEM achievement between genders are inextricably entwined in educational design contexts, as opposed to ability differences between students. Those topics with higher levels of abstract learning material, which involve more formalized learning activities, along with those involving mostly formative assessment designs, tend to be more prone in achievement gaps. Those involving programming, which are dominated by application tasks, projects, formative assessment, as well as group learning design, tend to be more equal.

These findings have real implications for instructors and curriculum developers working on first-year STEM courses. The study points to the need for rethinking instructional organization in conceptually demanding courses by incorporating structured problem-solving scaffolds, diversified assessment strategies, and interactive learning activities. Embedding formative assessment, worked examples, and collaborative activities into mathematics-intensive subjects could be one way to ameliorate observed gender differences.

At the institutional level, universities are called upon to offer specific pedagogical support for students in at-risk STEM courses by offering preparatory workshops, mentoring schemes, and curriculum redesign. By reorienting teaching practices to evidence-based didactic principles, higher education institutions can ensure more inclusive and equitable learning spaces that promote the academic success of both male and female students.

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STEM ПӘНДЕРІ БОЙЫНША БІРІНШІ КУРС СТУДЕНТТЕРІНІҢ АКАДЕМИЯЛЫҚ ҮЛГЕРІМІНДЕГІ ГЕНДЕРЛІК АЙЫРМАШЫЛЫҚТАР

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Аңдатпа. STEM білім берудің үздіксіз дамуы және академиялық жетістіктердегі гендерлік айырмашылықтар туралы пікірталастар аясында студент жігіттер мен студент қыздардың арасындағы академиялық көрсеткіштердегі нақты айырмашылықтарды анықтау өте өзекті болып қала береді. Бұл зерттеу STEM бағдарламалары бойынша білім алып жатқан бірінші курс студенттерінің академиялық көрсеткіштеріндегі гендерлік айырмашылықтарды зерттейді.

Зерттеудің мақсаты - негізгі STEM курстарындағы студент жігіттер мен студент қыздар арасындағы академиялық көрсеткіштердегі айырмашылықтарды анықтау және талдау, сондай-ақ STEM пәндеріндегі студент жігіттердің артықшылығы туралы жалпы болжамдарды бағалау. Зерттеу нақты академиялық деректерге негізделген эмпирикалық дәлелдер келтіру арқылы жоғары білім берудегі гендерлік теңдік туралы академиялық пікірталасқа үлес қосады.

Бұл зерттеудің ғылыми маңыздылығы STEM білім берудегі гендерлік айырмашылықтар туралы эмпирикалық білім базасын кеңейтуде, ал оның практикалық маңыздылығы жоғары оқу орындарында инклюзивті білім беру саясаты мен қолдау стратегияларын әзірлеуде нәтижелерді қолдану мүмкіндігінде жатыр. Зерттеудің әдіснамалық негізі - сипаттамалық статистика және параметрлік емес статистикалық талдау. 2021-2023 оқу жылдарындағы мұрағатталған және анонимделген бірінші курс студенттерінің академиялық жазбалары Манн-Уитни U тесті арқылы талданды. Деректер жиынтығына бес кіріспе STEM курстарындағы студенттердің көрсеткіштері кірді.

Нәтижелер бес курстың төртеуінде студент қыздар студент жігіттерге қарағанда статистикалық тұрғыдан айтарлықтай жоғары орташа балл жинағанын көрсетті. Бағдарламалау және алгоритмдер курсында статистикалық тұрғыдан маңызды гендерлік айырмашылықтар табылған жоқ. Бұл зерттеулер STEM салаларында студент жігіттердің артықшылығы туралы терең қалыптасқан стереотиптерге күмән келтіреді және әлеуметтік-

мәдени, психологиялық және білім беру факторларының академиялық көрсеткіштерге әсерін көрсетеді.

Бұл зерттеудің құндылығы STEM білім берудегі гендерлік теңдікке дәлелді тәсілдерді дамытуға қосқан үлесінде жатыр. Практикалық салдарға инклюзивті оқыту әдістерін және мақсатты академиялық қолдау бастамаларын дамыту жатады.

Тірек сөздер: гендерлік айырмашылықтар, STEM білім беру, академиялық жетістік, гендерлік теңдік, сандық талдау, инклюзивті педагогика, білім беру саясаты, жоғары білім

ГЕНДЕРНЫЕ РАЗЛИЧИЯ В АКАДЕМИЧЕСКОЙ УСПЕВАЕМОСТИ СТУДЕНТОВ ПЕРВОГО КУРСА В STEM ДИСЦИПЛИНАХ

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Аннотация. В контексте продолжающегося развития STEM-образования и постоянных дискуссий о гендерном неравенстве в академической успеваемости вопрос выявления реальных различий в успеваемости между студентами мужского и женского пола остается весьма актуальным. Данное исследование посвящено изучению гендерных различий в академической успеваемости среди студентов первого курса университетов, обучающихся по STEM-программам.

Цель исследования – выявить и проанализировать различия в академической успеваемости между студентами мужского и женского пола по базовым STEM-курсам и оценить распространенные предположения о преимуществе мужчин в STEM-дисциплинах. Исследование вносит вклад в академическую дискуссию о гендерном равенстве в высшем образовании, предоставляя эмпирические данные, основанные на реальных академических данных.

Научная значимость данного исследования заключается в расширении эмпирической базы знаний о гендерных различиях в STEM-образовании, а его практическая значимость связана с потенциальным применением полученных результатов в разработке инклюзивной образовательной политики и стратегий поддержки в высших учебных заведениях.

Методологически исследование основано на описательной статистике и непараметрическом статистическом анализе. Архивированные и анонимизированные академические записи студентов первого курса за 2021-2023 годы были проанализированы с использованием критерия Манна-Уитни. Набор данных включал успеваемость студентов по пяти вводным курсам STEM.

Результаты показали, что в четырех из пяти курсов студентки получили статистически значимо более высокие средние оценки, чем студенты. В курсе по программированию и алгоритмам статистически значимых гендерных различий выявлено не было. Эти результаты бросают вызов глубоко укоренившимся стереотипам о присущем мужчинам превосходстве в областях STEM и подчеркивают влияние социокультурных, психологических и образовательных факторов на академическую успеваемость.

Ценность этого исследования заключается в его вкладе в продвижение научно обоснованных подходов к гендерному равенству в STEM-образовании. Практические последствия включают в себя разработку инклюзивных методов обучения и целевых инициатив по академической поддержке.

Ключевые слова: гендерные различия, STEM-образование, академическая успеваемость, гендерное равенство, количественный анализ, инклюзивная педагогика, образовательная политика, высшее образование

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