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Article

Investigating the Impact of Student-Assisted E-Learning Delivery (SAED) Program on Academic Performance and Learning Management System Engagement: Insights from a Large-Scale University Study

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Abstract: **Background**: **Background**: Learning Management Systems (LMS) have facilitated a pivotal change in educational practices by enhancing content dissemination and enabling data-driven insights into pedagogical strategies. However, their full potential might not be realized without mutual engagement between faculty and students. The Student Assistant E-Learning Delivery (SAED) program addresses this by developing student-faculty partnerships leveraging trained student assistants to be active members of the e-learning delivery. Objective: This study evaluates SAED's impacts on student achievement and Blackboard engagement across a large, diverse university population using exploratory data analysis. **Methods**: Data from 2223 students enrolled in 24 university courses, both with SAED implementation and non-SAED controls, were analyzed. Course pass percentages, average section scores, individual student scores, and Blackboard platform metrics were compared between the SAED and control groups. SAED effects were evaluated overall and within subgroups determined by semester, sex, campus, discipline, faculty, and course. **Results**: The study observed high overall pass rates (98.1%) and average course section scores (4.3 out of 5.0), indicating robust academic performance. There was no significant difference in pass rates and scores between SAED and control groups. Notably, SAED had a positive impact on scores for female students and those in the Humanities/Social Sciences college, while it showed lower scores in males and the Law/Political Science college compared to the control group. SAED yielded comparable Blackboard engagement to

non-SAED control groups. Interestingly, higher exam scores were correlated with lower item counts on Blackboard. **Conclusion**: The SAED program offers an effective strategy to facilitate e-learning while achieving equitable outcomes to standard "sole faculty-delivery" approaches. However, findings reveal untapped opportunities to engage student assistants as partners in pedagogical innovation and course enhancement beyond basic support roles.

Keywords: Student achievement; Blackboard; Blended learning; SAED; The Assistant Student; Exploratory data analysis (EDA)

1. Introduction

In recent years, the development and spread of e-learning and online education have accelerated, especially after the Covid-19 pandemic. This caused a major shift in universities' education strategies, with distance learning becoming mandatory due to campus closures and the suspension of in-person classes worldwide. This represented emergency education during the crisis [1].

The advent of digital technologies alongside advancements in social science research has demonstrated immense potential to enhance students' intellectual agility, knowledge acquisition, skill building, and ability to meaningfully participate in the digital era [2,3]. Online learning management systems offer advantages for both instructors and students by enabling more smooth, professional, and effective communication [4]. Faculty can manage courses, create lectures, upload content, design assessments, and enable communication. Students can access materials, attend virtual classes, and interact with instructors and peers [5,6].

While the Blackboard platform offers many valuable features, prior studies indicated its adoption by faculty was limited [7,8]. Several studies have been conducted to elucidate factors that could contribute to this phenomenon [9-11]. It was found that unawareness of e-learning benefits and limited technology familiarity posed key challenges against proper LMS adoption [12,13].

The utilization of Blackboard by faculty members at King Saud University was consistent with other universities, with a small percentage of users not exceeding 20% [14], despite its availability since 2011. However, the shift to distance education and the adoption of the Blackboard platform during the COVID-19 pandemic highlighted the importance of all faculty members utilizing Blackboard. In response, the university conducted numerous training courses, both in-person and online, and provided educational resources on its e-learning platform to facilitate Blackboard usage. While many faculty members benefited from these initiatives, a significant portion still did not utilize Blackboard. The rapid, unexpected transition from in-person to distance learning posed legitimate challenges for some faculty members. While technology offers many benefits, effectively leveraging it to transform pedagogy requires time and training that was not initially available. Understandably, the sudden shift to online education could feel daunting and complex without the proper support systems in place [11,15,16]. These systemic gaps left some instructors underprepared as they worked to navigate unfamiliar virtual teaching environments to the best of their abilities. However, forward progress requires a constructive approach to provide faculty with the technology training, instructional design partnership, and e-learning scaffolding needed to transition successfully

In the Fall semester of 2018, the Center for Excellence in Learning and Teaching at King Saud University (CELT_KSU) introduced an innovative initiative named the Assistant Student or "SAED" project. The primary objective of this project was

to enhance the utilization of Blackboard across the university by enlisting the assistance of technologically skilled students. These students were tasked with providing technical support and carrying out various tasks on the Blackboard platform on behalf of faculty members. The initial outcomes of this initiative were positive, leading to a recommendation for its expansion to all colleges and institutes within the university.

This initiative proved to be incredibly beneficial, especially during the COVID-19 pandemic when the need for emergency distance education arose. It aimed to ensure equal opportunities in education for all students, minimizing disruptions in the learning process and enabling every student to receive continuous, high-quality education on Blackboard, regardless of their circumstances [17]. Even post-pandemic, the SAED program continued to empower faculty members with valuable assistance. This allowed instructors to actively integrate online educational tools like Blackboard into their on-campus teaching methods.

The primary goal of the "SAED" initiative was to support faculty members in effectively utilizing Blackboard, especially those less accustomed to e-learning tools. This was achieved through collaborative partnerships with student assistants who received specialized training from CELT-KSU. By pooling their respective strengths, faculty members and student assistants worked together to enhance educational experiences on Blackboard. Student assistants contributed skills in areas like uploading content, facilitating online discussions, and communicating with the students. Faculty members maintained exclusive authority over assessments and grades while benefiting from student guidance on other less-sensitive components. This cooperative approach allowed instructors to focus on pedagogical priorities while student partners supplemented technical expertise.

To evaluate the effectiveness of the "SAED" project, CELT conducted a previous study during the COVID-19 pandemic [17]. The study concluded that the initiative

significantly increased faculty members' use of the Blackboard platform, enhancing efficiency, continuity, and motivation in incorporating Blackboard into their teaching practices. Furthermore, faculty members who experienced the benefits of the initiative encouraged their colleagues to utilize Blackboard or participate in the "SAED" initiative.

Considering the success of the initiative, the researchers recommended that other educational institutions implement similar initiatives due to their positive impact on increasing faculty members' use of Blackboard and technology in education. By doing so, these institutions can uphold the principle of providing equal opportunities in education for all students.

However, the previous study focused solely on faculty perception of the SAED program during distance learning (specifically during COVID-19) and did not assess its impact on student achievements such as pass rates, scores, and attributes related to Blackboard interaction. Furthermore, there is a lack of extensive research on the benefits of implementing the SAED program at the university level.

In contrast, the current study aims to address these gaps by assessing the effect of SAED on student scores using a substantial group of students with diverse academic backgrounds, university campuses, and study levels. Additionally, this study introduces a novel approach by utilizing the high-level programming language Python 3 for a comprehensive Exploratory Data Analysis (EDA) of students' scores and their perceptions of Blackboard interaction.

The study intends to answer critical questions such as:

What is the overall and differential impact of the SAED program on academic achievement, taking into account various confounding factors?

What is the overall and differential impact of the SAED program on Blackboard usage and student interactivity, while accounting for various confounding factors?

Is there a significant correlation between Blackboard usage, student interaction, and academic achievements?

By addressing these research questions, the study aims to provide valuable insights into the impact of the SAED program on both academic achievement and students' engagement with the Blackboard platform.

2. Materials and Methods

2.1. Study design

This study utilized a two-group quasi-experimental design. Course sections were assigned to either the SAED treatment group or the control (non-SAED) group based on voluntary faculty participation. Sections taught by opt-in faculty were designated as the SAED group. The remaining course sections taught by non-participating faculty served as the control (non-SAED) group.

2.2. Study setting

The study was conducted in the 2nd and 3rd semesters - 2023 and involved 24 undergraduate courses within 9 colleges covering the 4 scientific disciplines at King Saud University.

2.3. Procedure

The Student Assistant (SAED) lead program was initiated and coordinated by the Center for Excellence in Learning and Teaching at King Saud University

(KSU-CELT). At the start of each semester, CELT-KSU made a public call for voluntary SAED participation directed at all university faculties.

Course instructors who opted to participate had their sections assigned to the SAED group and requested student assistant permissions for one of their enrolled students. These students then received specialized training from CELT-KSU on utilizing Blackboard from the instructor's perspective, rather than the student's view [17].

After completing training, the student assistants were granted permission to build content within the Blackboard system, upload assignments and lectures, and support the enrolled section under faculty supervision. However, permissions such as creating exams or viewing grade reports were maintained and restricted to faculty members only.

To prevent spillover, student assistants were only granted access to the specific section they were enrolled in. They had no Blackboard permissions in the control group sections. This helped ensure the SAED intervention was only implemented in the participating faculty sections, while control sections did not receive SAED support.

Finally, Academic performance data (grades, pass rates) and blackboard usage metrics were compared between the two groups.

2.4 Participant Incentives

Highly active and Senior assistant students who actively participate in training new candidates were eligible for financial support for their efforts in the program.

2.5. Participant Demographics

The SAED program was successfully incorporated into 24 undergraduate courses by 14 faculty members from various colleges (see Table 1). Certain sections of each course implemented the SAED program, while other sections that did not implement SAED were used as a control (non-SAED) group. A total of 2505 undergraduate students were initially enrolled in the score analysis study (see Figure 1). However, some students and sections were excluded from the score analysis study for the following reasons:

- Two sections (71 students) that did not implement SAED had no sex information (categorization as male or female) available from the score analysis data.
- Four courses (76 students) had only one section, which implemented SAED, but no control group (non-SAED group) was available.
- One course had three sections (20 students) that did not implement SAED.
- 114 students withdrew from their courses early in the semester.
- One student did not attend the final exam but took a make-up exam, and his/her score was not available.

As a result, a total of 2223 students (95 sections, 6 colleges, and 19 courses) were included in the subsequent score analysis

Table 1. List of courses and their abbreviations.

Course Name	**Abbreviation**
Asset Management	AM
Islamic Jurisprudence of Marriage Dissolution	IJMD
Biopsychology -2-	BP2
Psychopharmacology	PP
Sharia Politics	SP
Instructional Design	ID

Interpretation of the Quranic verses regarding legal rulings	IQV-LR
E-Learning Project Management	E-LPM
Discussion Circle in Education Techniques (3)	DC-ET3
Child Health Nursing	CHN
Fundamentals of Legal Research	F-LR
Corporate Law	CL
Political Systems of Neighboring Countries	PS-NC
Principles of Genomic Pharmacy	P-GP
General Virology	GV
Foundations of Social Service	F-SS
Introduction to Social Care	I-SC
Social Research Methodologies	SRM
Human Behavior and the Social Environment	HB-SE
Saudi Arabian Society	SAS
Predictive Sociology and Future Studies	PS-FS
Advanced Statistics and Information Processing	AS-IP
Professional Ethics	PE
Selected Topics in Engineering and Construction Management	ECM

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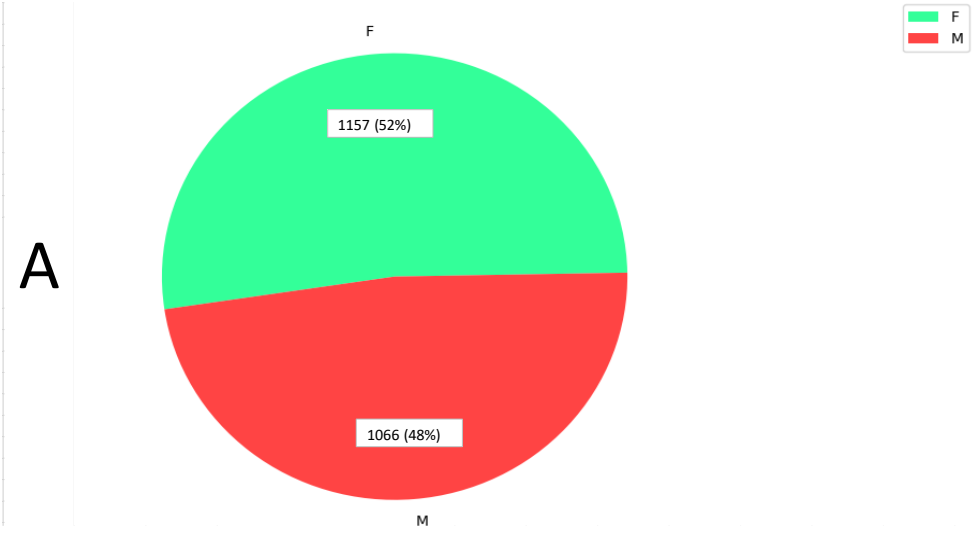
The demographic data indicates that the study encompassed a broad range of student and university characteristics. Notably, he data showed a relatively even distribution between males and females. (Figure 1A) and spanned two consecutive semesters in 2023 (Figure 1B). The study also included five university campuses, with the majority (40%) of participants belonging to Male campus #1 (Figure 1C). Additionally, the study had a good distribution across different disciplines, covering six colleges (including three scientific disciplines) within the university (Figures 2D and 2E). Interestingly, the majority of participating students (60%) were from the humanities discipline. Most importantly, 22% of enrolled students benefited from the SAED program in their courses, while the remaining 78% represented the control group that did not implement SAED (Figure 1F).

A



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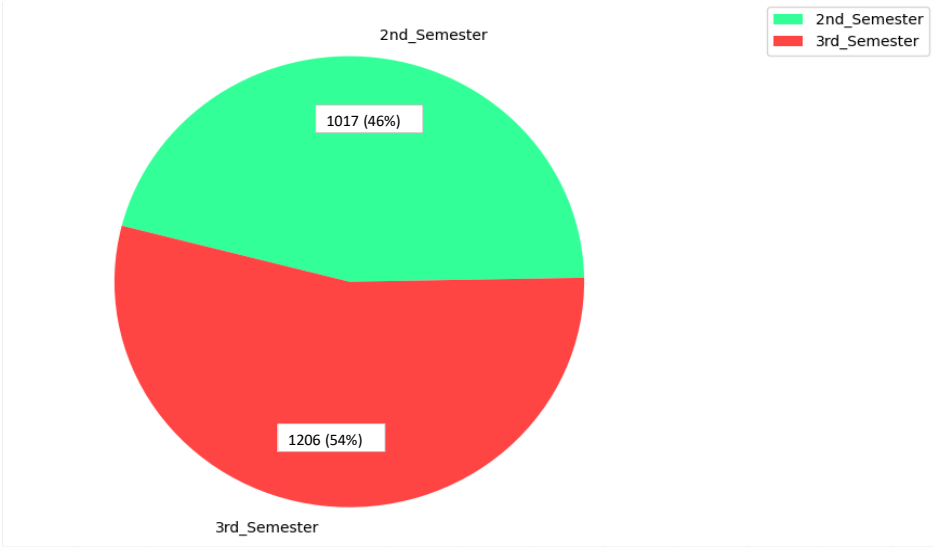
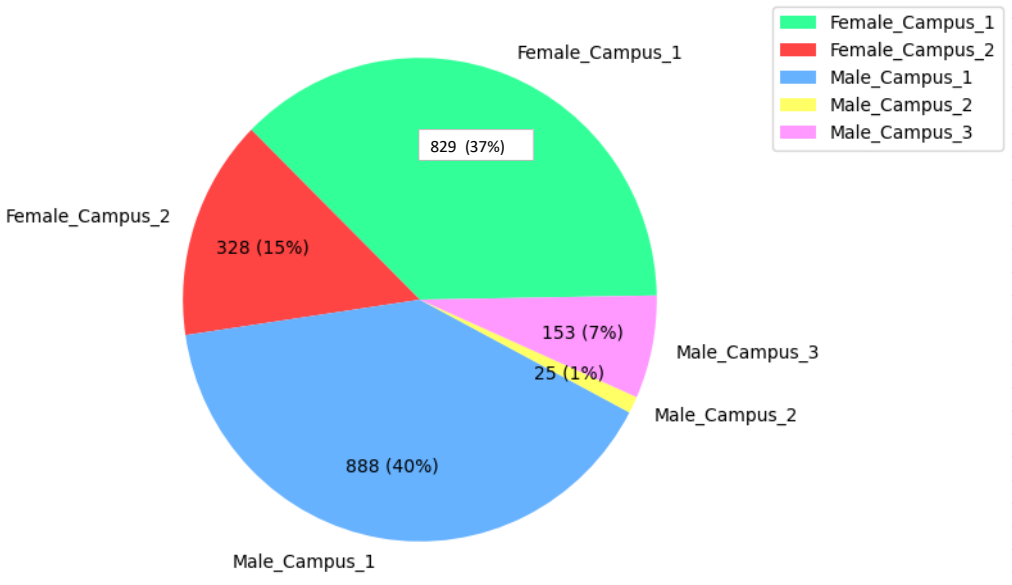
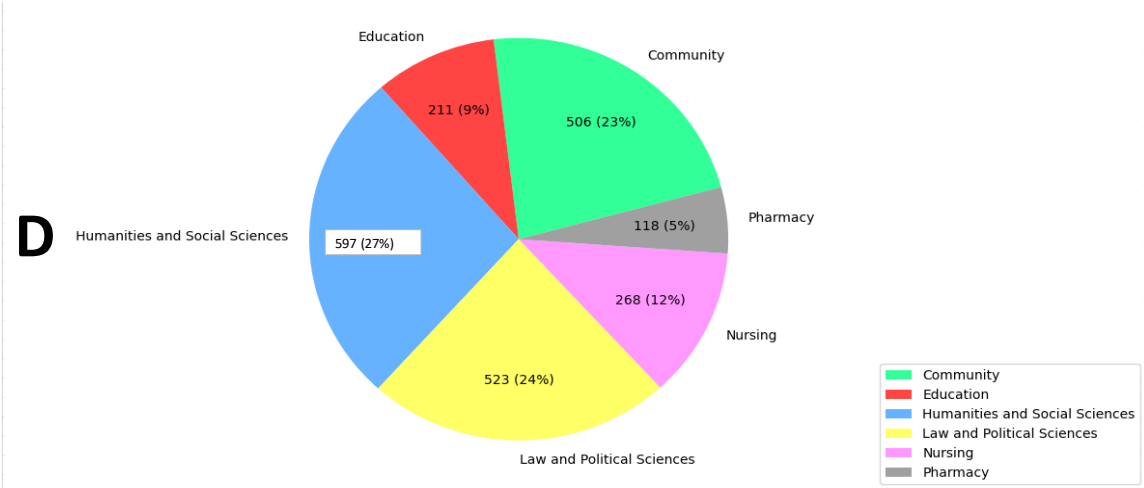
B



C


Female_Campus_1
Female_Campus_2
Male_Campus_1
Male_Campus_2
Male_Campus_3
829 (37%)
328 (15%)
153 (7%)
25 (1%)
888 (40%)
Female_Campus_1
Male_Campus_3
Male_Campus_2
Female_Campus_2
Male_Campus_1

D


Education
Community
211 (9%)
506 (23%)
Pharmacy
118 (5%)
Humanities and Social Sciences
597 (27%)
268 (12%)
Nursing
523 (24%)
Law and Political Sciences
Community
Education
Humanities and Social Sciences
Law and Political Sciences
Nursing
Pharmacy

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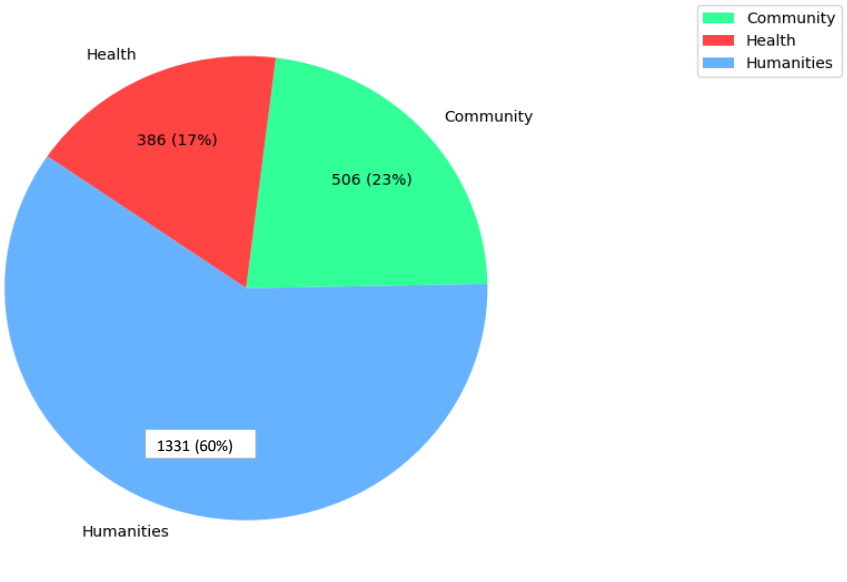
E



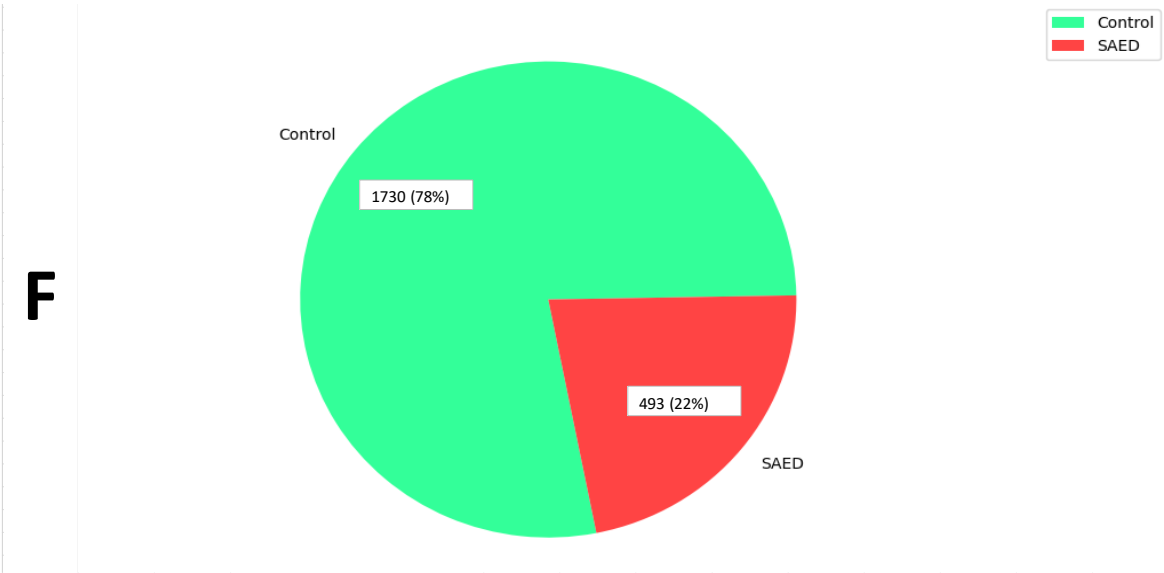


Figure 1. The distribution of students according to (A) Sex, (B) Semester, (C) Campus, (D) Faculty, (E) Scientific discipline, and (F) SAED implementation.

2.3. Assessment of Student Outcomes

At the end of the semester, anonymous data on final exam scores were obtained from KSU's Deanship of Admission and Registration Affairs. This data encompassed information on the total number of students in each section who were registered, dropped out, studied, or prohibited. It also detailed the number of students who passed or failed, along with their distribution across various score ranks from D to A+. This data was reshaped using Python to focus on three key features: Pass rate (%), Student score, and Average section score. The pass rate was determined as the percentage of students who received a grade of D or higher, while the

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average section and student scores were calculated using KSU's grading system (DN or F: 1 up to A+: 5).

2.4. Analysis of Blackboard usage and student engagement

Anonymous data on online learning adoption and student interaction metrics in Blackboard were obtained from King Saud University's Deanship of e-Transaction and Communication. This data aimed to assess the levels of course activities and student engagement within specific course sections. It encompassed information on the item count, course interactions, and average activity by course content (%) for each course as follows:

- Item count - Number of learning objects/items posted in each course section.
- Course interactions - Number of clicks students performed within each course section.
- Normalized Course interactions per student - Calculated by dividing the total interactions by the number of unwithdrawn students within each course section. This normalized the interaction data based on completing student numbers.
- Average activity by course content (%) – the percentage of overall course content that saw student interaction on average within each section.

This Blackboard data allowed for comparisons of course design richness/breadth as indicated by item counts, and student engagement as reflected by interaction counts across different course sections that did and did not utilize the "SAED" program support. The objective was to assess the impact of the SAED program on these online learning environment attributes and to assess the correlation between these attributes and Average Section Score.

Course sections with inappropriate and/or missing data were excluded from the study. As a result, the comparative statistical analysis comprised 7 courses from

the second semester while the correlation analysis included 11 courses from that semester.

2.5. Data Analysis

2.5.1. Sampling

In an initial analysis of student scores, a substantial discrepancy in sample sizes was noted between the SAED and control cohorts (Fig. 2F). A closer look revealed that in larger classes, such as PE (n = 506 students), the control groups had approximately 8.7 times more students than the equivalent SAED groups. This imbalance resulted in skewed calculations of the average scores for each subgroup and increased the likelihood of a type 1 error during the evaluation of study variables due to an unbalanced distribution of students according to possible confounding factors (disproportionate sizes of SAED/control in each class). To address this issue, a random sampling approach was adopted from the original dataset (Table 2). For each class, sampling was performed only on the larger group (SAED or control) to balance the number of students in the SAED/control groups within each class [3]. The sampling was carried out using the sample function from the pandas python library, ensuring the average score of all the sampled data was not significantly different from the raw unsampled data ($p > 0.05$) (Table 2). Consequently, the next steps of statistical analysis of the pass rate (%) and student scores were based on this adjusted data.

2.5.2. Software

The analysis of the data in this study was primarily conducted using the Python programming language (version 3.9.13) within a Jupyter Notebook environment (jupyter_core: 4.11.1, notebook server: 6.4.12). A variety of packages, including pandas, numpy, seaborn, matplotlib, itertools, and statannotations were employed

for tasks such as presenting data, organizing it into groups, validating it, manipulating data frames, and generating visualizations. Parts of this manuscript were crafted with drafting with the assistance of automated writing programs like Claude, and Copy.ai, as well as Microsoft's AI chatbot. Some Python code scripts used for associated data processing benefited to some extent from guidance provided by those artificial intelligence tools. Notwithstanding, the authors held accountability for the concepts explored, the substance covered, and the final form of the manuscript.

2.5.3. Statistical analysis

The normality of the data was determined using Shapiro-Wilk test from the SciPy. Stats Python package [18]. For dependent variables that were binary (e.g. pass/fail), the data were analyzed statistically using a chi-square test for independence in a contingency table to evaluate two independent samples. When there were more than two samples, a Bonferroni post-hoc adjustment following chi-square was utilized. These analyses were conducted using functions in the Scipy Python package [19,20].

Other dependent variables that were discrete or continuous were assessed using the Mann-Whitney U test for two independent samples (stat annotations python package) or the Wilcoxon signed-rank test for two paired samples (Scipy. stats python package). For more than two samples, a Kruskal-Wallis H test followed by post-hoc Dunn's test with Bonferroni correction was applied, drawing on functions from the Pingouin and Scikit-Posthocs packages [21].

Correlational analysis involved Spearman's correlation test using Scipy functions [22]. For all statistical tests, a p-value of ≤ 0.05 was considered statistically significant.

Table 2. Comparison of Student Distribution by Subcategories: Raw Data vs Sampled Data.

SCIENTIFIC_DISCI-PLINE	FACULTY_DESC	COURSE_CODE	Program Implementa-tion	Raw data (n)	Sampled Data (n)	*p*-value *
Community	**Community**	**PE**	**Control**	454	52	0.43
			SAED	52	52	1.00 #
Health	**Nursing**	**CHN**	**Control**	237	31	0.87
			SAED	31	31	1.00 #
	Pharmacy	**P-GP**	**Control**	66	52	0.72
			SAED	52	52	1.00 #
Humanities	**Education**	**BP2**	**Control**	39	19	0.91
			SAED	19	19	1.00 #
		DC-ET3	**Control**	3	3	1.00 #
			SAED	7	3	1.00
		E-LPM	**Control**	22	9	1.00

		SAED	9	9	1.00 #
	ID	**Control**	12	9	0.79
		SAED	9	9	1.00 #
	IQV-LR	**Control**	13	13	1.00 #
		SAED	16	13	0.80
	PP	**Control**	22	22	1.00 #
		SAED	23	22	0.85
	SP	**Control**	14	3	1.00
		SAED	3	3	1.00 #
Humanities and Social Sciences	**AS-IP**	**Control**	9	9	1.00 #
		SAED	10	9	0.89
	F-SS	**Control**	115	105	0.84
		SAED	105	105	1.00 #
	HB-SE	**Control**	4	4	1.00 #
		SAED	9	4	0.68
	I-SC	**Control**	90	39	0.75

		SAED	39	39	1.00 #
	PS-FS	**Control**	7	7	1.00 #
		SAED	11	7	0.96
	SAS	**Control**	161	25	0.32
		SAED	25	25	1.00 #
	SRM	**Control**	6	6	1.00 #
		SAED	6	6	1.00 #
Law and Political Sciences	**CL**	**Control**	226	30	0.12
		SAED	30	30	1.00 #
	F-LR	**Control**	230	37	0.82
		SAED	37	37	1.00 #

* The p-value indicates the statistical significance of the difference in average scores between the raw and sampled data for each course. # denotes that the sampled data contains the same values as the raw data.

3. Results

3.1. Study Overview

The study included 2505 students who were enrolled in the 2nd and 3rd semesters of 2023. The study was conducted across 105 sections, with an average of 23 students in each section (Table 3). The average rates for passing, prohibition, and failure were 98.1%, 0.1%, and 1.4%, respectively. Notably, the average score achieved by students was 4.3 out of a possible 5.0, with over half (51.8%) of students achieving a score of at least 4.75 (equivalent to an A+ or A grade).

Table 3. Score Analysis Study: Descriptive Statistics Across Sections (n = 105).

Study parameters	TOTAL_REGISTERED _STUDENTS	Unwithdrawn Students	Passing rate (%)	Prohibition rate (%)	Failure rate (%)	Average section score (out of 5)	A+ (%)	A (%)	B+ (%)	B (%)	C+ (%)	C (%)	D+ (%)	D (%)
mean	23.9	22.6	98.1	0.1	1.4	4.3	30.3	21.5	17.5	10.8	8.6	5.0	1.9	2.8
std	16.2	15.8	4.6	0.7	4.2	0.5	28.6	14.4	17.6	9.8	10.8	6.4	3.9	6.9
min	1.0	1.0	72.7	0.0	0.0	2.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25%	11.0	11.0	100.0	0.0	0.0	4.0	5.3	11.1	5.9	0.0	0.0	0.0	0.0	0.0
50%	23.0	21.0	100.0	0.0	0.0	4.4	25.0	20.0	14.3	9.7	4.8	2.1	0.0	0.0
75%	31.0	30.0	100.0	0.0	0.0	4.7	48.0	30.0	23.6	17.6	15.4	8.0	2.0	2.9

max	101.0	98.0	100.0	4.8	27.3	5.0	100.0	75.0	100.0	38.9	50.0	24.0	18.2	50.0

Examination of the histograms for several key metrics revealed skewed distributions. Specifically, pass rate and overall score histograms showed a positive skew, whereas failure rate and prohibition rate histograms presented a negative skew. The Shapiro-Wilk test was used to assess normality, with significant p-values ($p < 0.05$) found for all metrics. Since normality is an underlying assumption of parametric tests, this result indicated the metrics were not normally distributed across the sampled data. Given the skew observed in the histograms and the non-normality test outcomes, parametric statistical approaches could not appropriately be applied to evaluate differences between study subgroups for these metrics. Therefore, non-parametric techniques, which do not require normality assumptions, were selected for subsequent analyses comparing the metrics across various categories within the data set [18].

3.2. Findings Related to Course Pass Percentage

The overall analysis of pass percentage results indicated that there was no statistically significant difference ($p = 0.26$) between the SAED and control group (Figure 2). Regarding other potential confounding factors, the comprehensive analysis found that all variables tested, including academic term, sex, campus location, faculty, field of study, and course type, similarly had no statistically significant impact on pass rates. Consistent with these findings, follow-up differential analyses exploring the impact of SAED involvement within subgroups defined by the various factors also detected no significant difference between SAED and control groups across categories of the semester, sex, campus, discipline, faculty course type, as illustrated in Figures 3A through 3F.

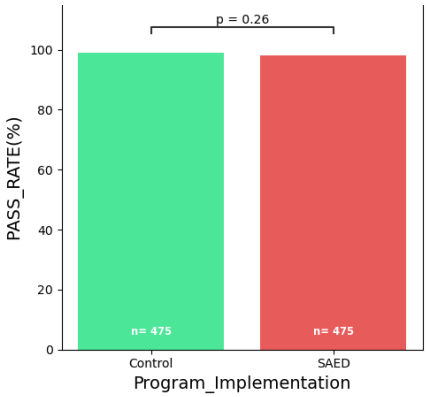

Figure 2. Evaluation of the overall influence of SAED implementation on pass rate outcomes.

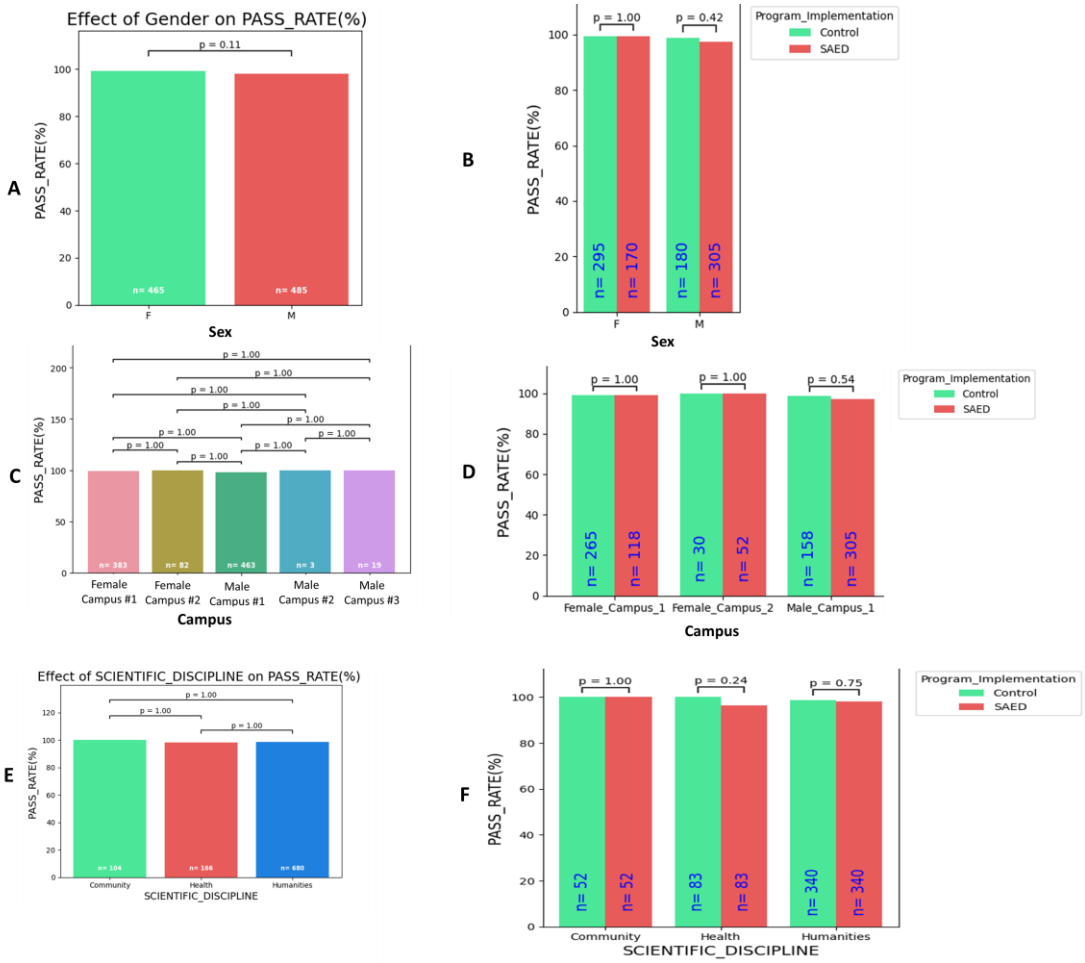
A
Effect of Gender on PASS_RATE(%)
p = 0.11
PASS_RATE(%)
n= 465
n= 485
F
M
Sex
B
p = 1.00
p = 0.42
Program_Implementation
Control
SAED
PASS_RATE(%)
n= 295
n= 170
n= 180
n= 305
F
M
Sex
C
PASS_RATE(%)
Female Campus #1
Female Campus #2
Male Campus #1
Male Campus #2
Male Campus #3
Campus
D
p = 1.00
p = 1.00
p = 0.54
Program_Implementation
Control
SAED
PASS_RATE(%)
n= 265
n= 118
n= 30
n= 52
n= 158
n= 305
Female_Campus_1
Female_Campus_2
Male_Campus_1
Campus
E
Effect of SCIENTIFIC_DISCIPLINE on PASS_RATE(%)
PASS_RATE(%)
Community
Health
Humanities
SCIENTIFIC_DISCIPLINE
F
p = 1.00
p = 0.24
p = 0.75
Program_Implementation
Control
SAED
PASS_RATE(%)
n= 52
n= 52
n= 83
n= 83
n= 340
n= 340
Community
Health
Humanities
SCIENTIFIC_DISCIPLINE

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Figure 3. Overall and subgroup analyses of the impact of potential confounding variables, including (A) academic term, (B) sex, (C) campus location, (D) field of study, € faculty, and (F) course type on pass rate (%).

3.3. Exam Scores

Similarly, the overall analysis of students' scores results indicated that there was no statistically significant difference ($p = 0.85$) between SAED and the control group (Figure 4). Looking at other factors, the analysis revealed that the academic term, field of study, and campus location had no significant impacts on students' scores when comparing their various subgroups (Figure 5A, 5E, 6C). However, sex, faculty, and course type did have significant effects on student scores (Figure 5C, 6A, and 7A, respectively). Specifically, female students demonstrated significantly higher scores than their male counterparts (Figure 5C). The Nursing College showed the highest average student scores compared to other colleges (Figure 6A). Interestingly, one of the representative courses from the Education college, namely DC-ET3, showed the significantly highest scores, while one of the courses from the Humanities and Social Sciences college, PS-FS, showed the lowest scores out of all courses analyzed (Figure 7A).

Given these significant effects of confounding factors, it was important to further investigate the differential effect of SAED use within each subset or subcategory of these factors. The detailed analysis of student scores detected no significant difference between SAED and control groups across categories of academic terms (Figure 5B) or fields of study (Figure 6D). However, interestingly, SAED showed significantly higher scores compared to the control (non-SAED) group specifically

for the Female subgroup and female campus #1, while the opposite finding was discovered for the male group and male campus #1, where the control had higher scores (Figure 5D, 5F). Similarly, SAED demonstrated significantly higher scores compared to control within the Humanities and Social Sciences college, while it showed significantly lower scores relative to control in the Law and Political Science college (Figure 6B). All other subgroups of campus and faculty showed no significant score differences between SAED and control.

Most importantly, at the individual course level, which represents the smallest subgroup that can partially account for differences in teaching style, course structure, evaluation methods, and other confounders, the analysis revealed that a total of 2 courses (I-SC and IQV-LR from Humanities/Social Sciences and Education) showed significantly higher scores for the SAED group versus control. In contrast, 3 courses (CL, F-LR, and PP from Law/Political Science and Education) showed significantly higher scores for the control non-SAED group compared to SAED. The remaining 15 analyzed courses across multiple disciplines demonstrated no significant in students' scores between SAED and the control group (Figure 7B).

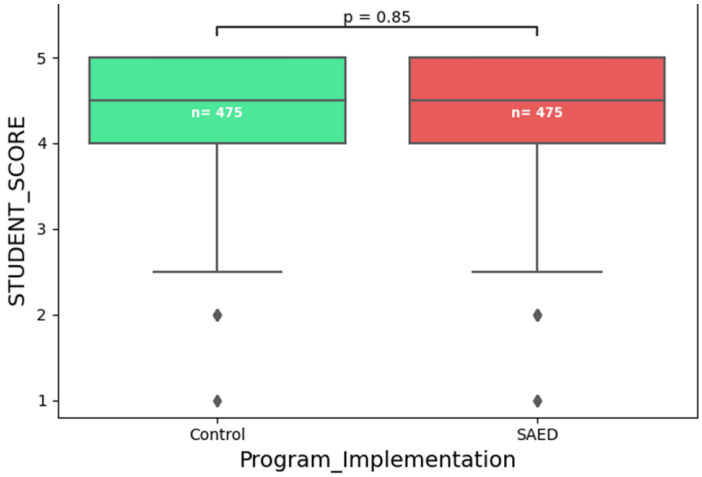
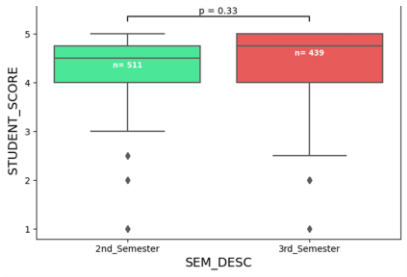
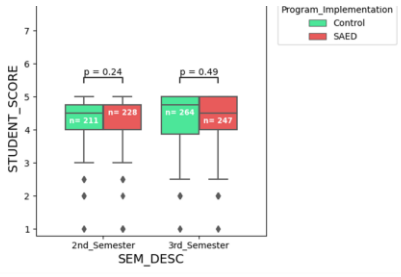


Figure 4. Evaluation of the overall influence of SAED implementation on student score outcomes.

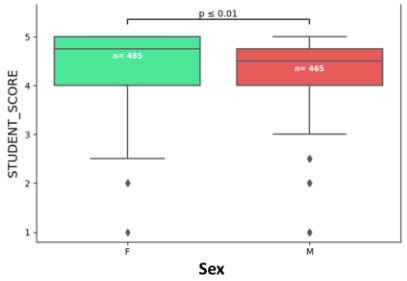
A


p = 0.33
n= 511
n= 439
STUDENT_SCORE
2nd_Semester
3rd_Semester
SEM_DESC

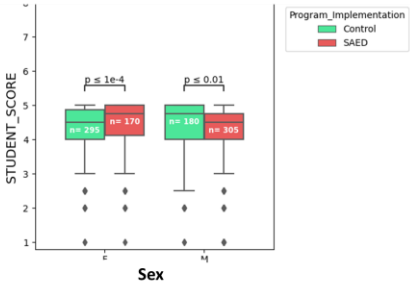
B


Program_Implementation
Control
SAED
p = 0.24
p = 0.49
n= 211
n= 228
n= 264
n= 247
STUDENT_SCORE
2nd_Semester
3rd_Semester
SEM_DESC

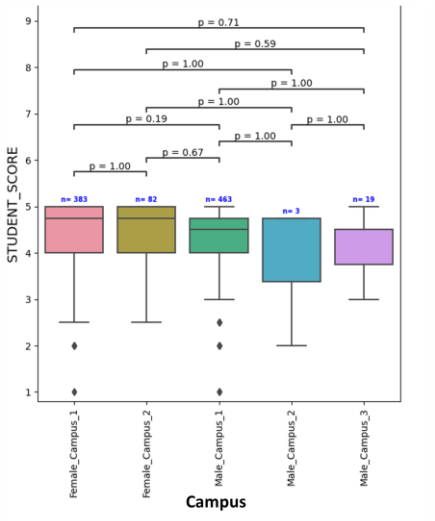
C


p ≤ 0.01
n= 485
n= 465
STUDENT_SCORE
F
M
Sex

D


Program_Implementation
Control
SAED
p ≤ 1e-4
p ≤ 0.01
n= 295
n= 170
n= 180
n= 305
STUDENT_SCORE
Sex

E


p = 0.71
p = 0.59
p = 1.00
p = 1.00
p = 1.00
p = 0.19
p = 1.00
p = 1.00
p = 0.67
p = 1.00
n= 383
n= 82
n= 463
n= 3
n= 19
STUDENT_SCORE
Female_Campus_1
Female_Campus_2
Male_Campus_1
Male_Campus_2
Male_Campus_3
Campus

F

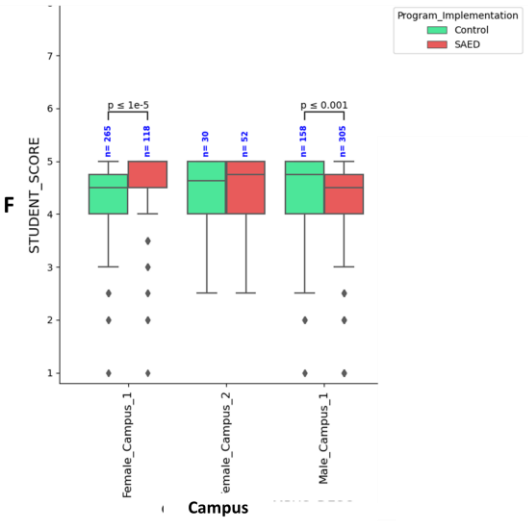

Program_Implementation
Control
SAED
p ≤ 1e-5
p ≤ 0.001
n= 265
n= 118
n= 30
n= 52
n= 158
n= 305
STUDENT_SCORE
Female_Campus_1
Male_Campus_1
Campus

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Figure 5. Overall and subgroup analyses of the impact of potential confounding variables, including (A,B) academic term, (C,D) sex, (E,F) campus location on student score outcomes.

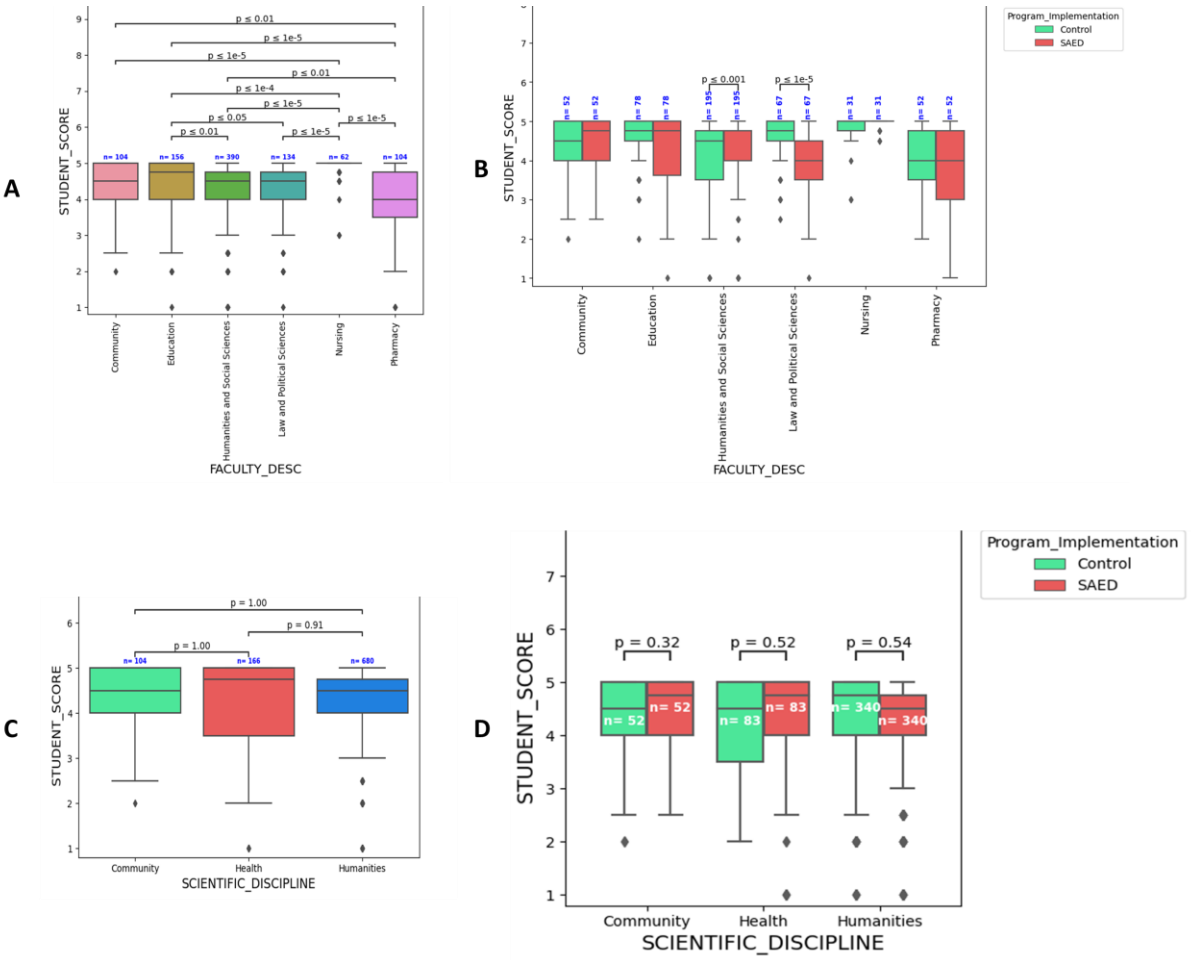

Figure 6. Overall and subgroup analyses of the impact of potential confounding variables, including (A,B) Faculty, (C,D) field of study on student score outcomes. In subfigures A, B: only significant p values were annotated.

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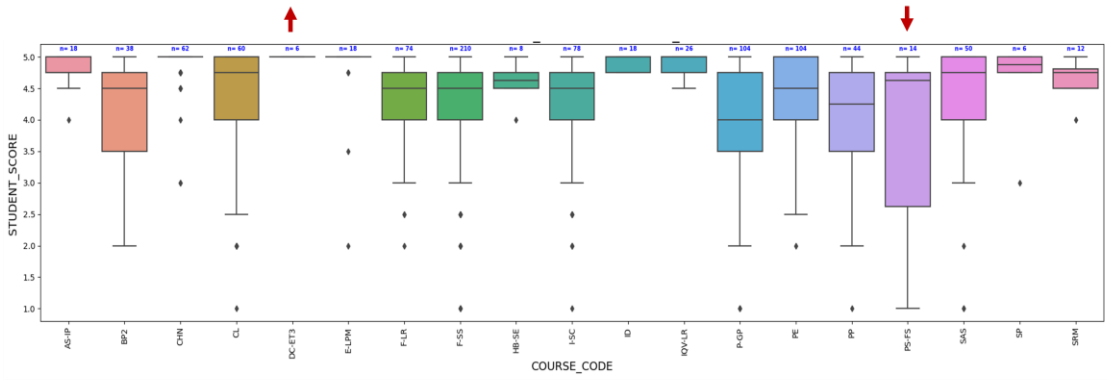
A



B

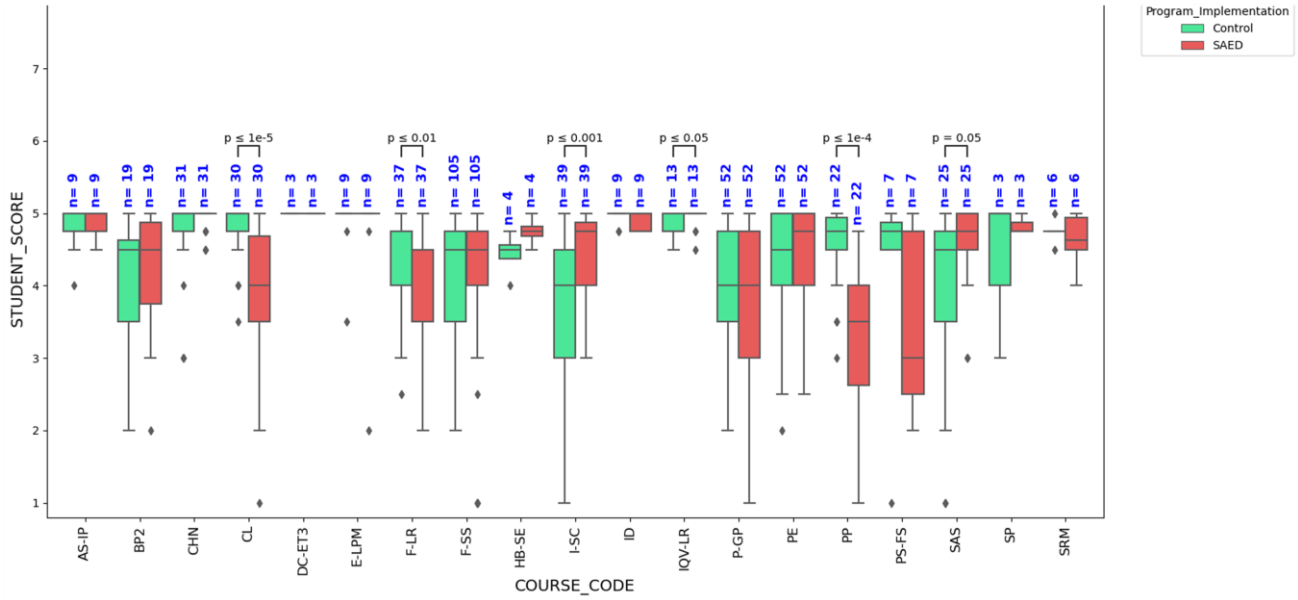


Figure 7. Overall and subgroup analyses of the impact of Course type on student score outcomes. (A) denotes the overall and (B) the subgroup effects. In subfigure A: only the lowest and highest scores were marked with the downward and upward red arrows. In Subfigure B: only significant p values were annotated.

3.4. Analysis of Blackboard Usage and Student Engagement

3.4.1. The impact of SAED program

At the individual course level, the analysis revealed that most courses showed comparable item counts and average activity percentages, except for course HB-SE where SAED showed approximately 3-fold higher activity percentage compared to the control section (Figure 8A and 8B). Regarding course interactions, SAED exhibited approximately 3-fold higher interactions than control groups in 2 courses, while the control group showed approximately 2-6-fold higher interactions than SAED in 3 courses (Figure 8C). Interestingly, upon normalization of course interactions based on student numbers, the control group demonstrated approximately 2-9-fold higher interactions than SAED in 3 courses (Figure 8D). While these discrepancies existed between the SAED and control groups for different courses and attributes, the overall analysis revealed no statistically significant difference ($p > 0.05$) between the SAED and control groups across all four attributes (Figure 9A-D).

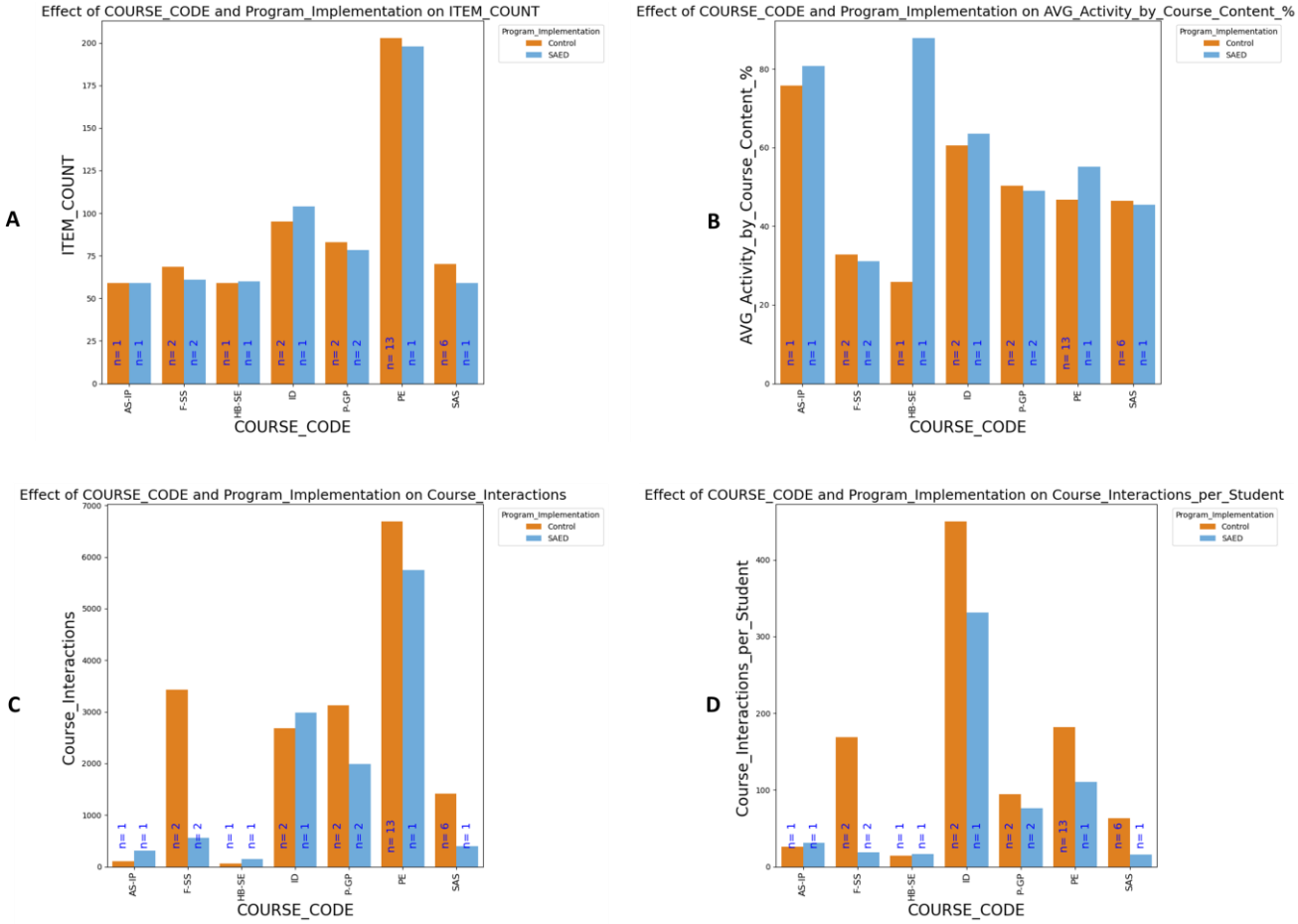


Figure 8. The individual impact of SAED program on (A) item count, (B) average activity by course content, (C) course interaction and (D) normalized course interaction per student at the course level.

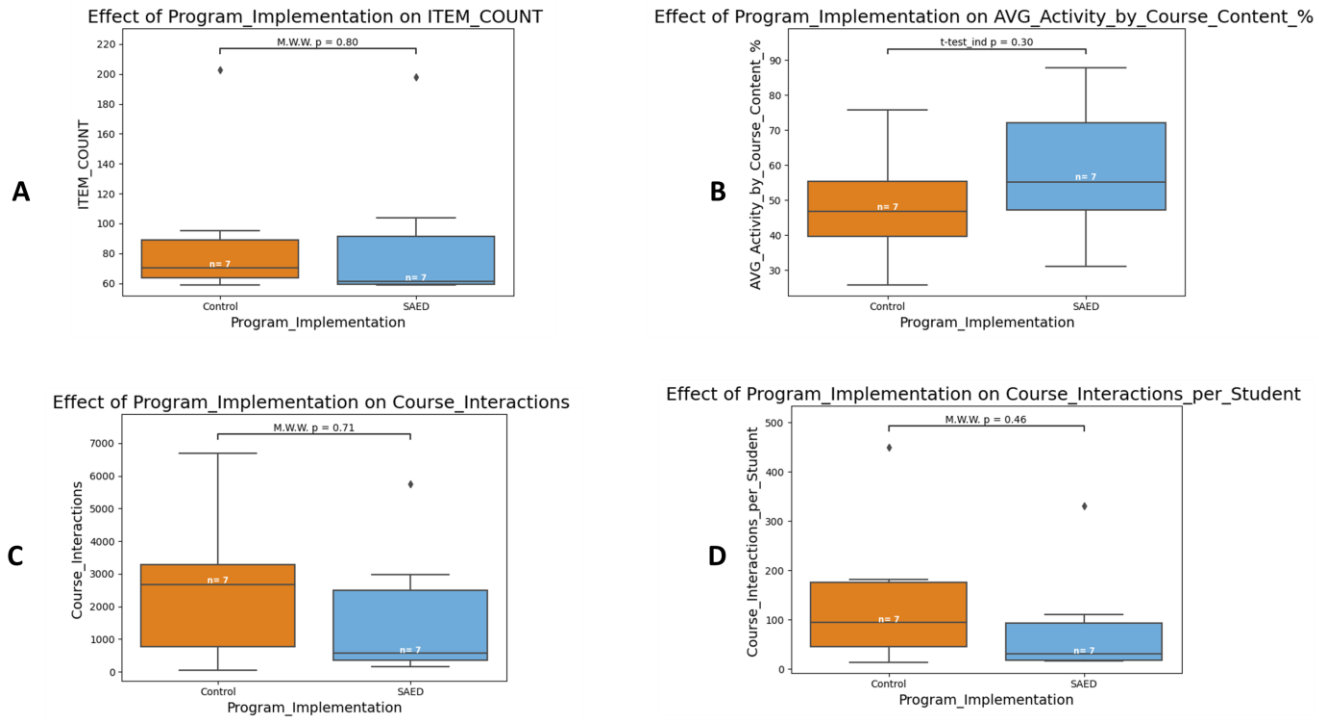


Figure 9. The overall impact of the SAED program on (A) item count, (B) average activity by course content, (C) course interactions, and (D) normalized course interactions per student. The SAED and control group means were calculated based on averaging the values of all sections within each course (n=7).

3.4.2. The correlation between course attributes/interactions and the score

Interestingly, the item count demonstrated a statistically significant ($p < 0.05$) moderate inverse correlation with the score (Figure 10A). However, the average activity by course content, course interactions, and its normalized value per student

exhibited non-significant ($p > 0.05$) negligible correlations with the score (Figure 10B-D).

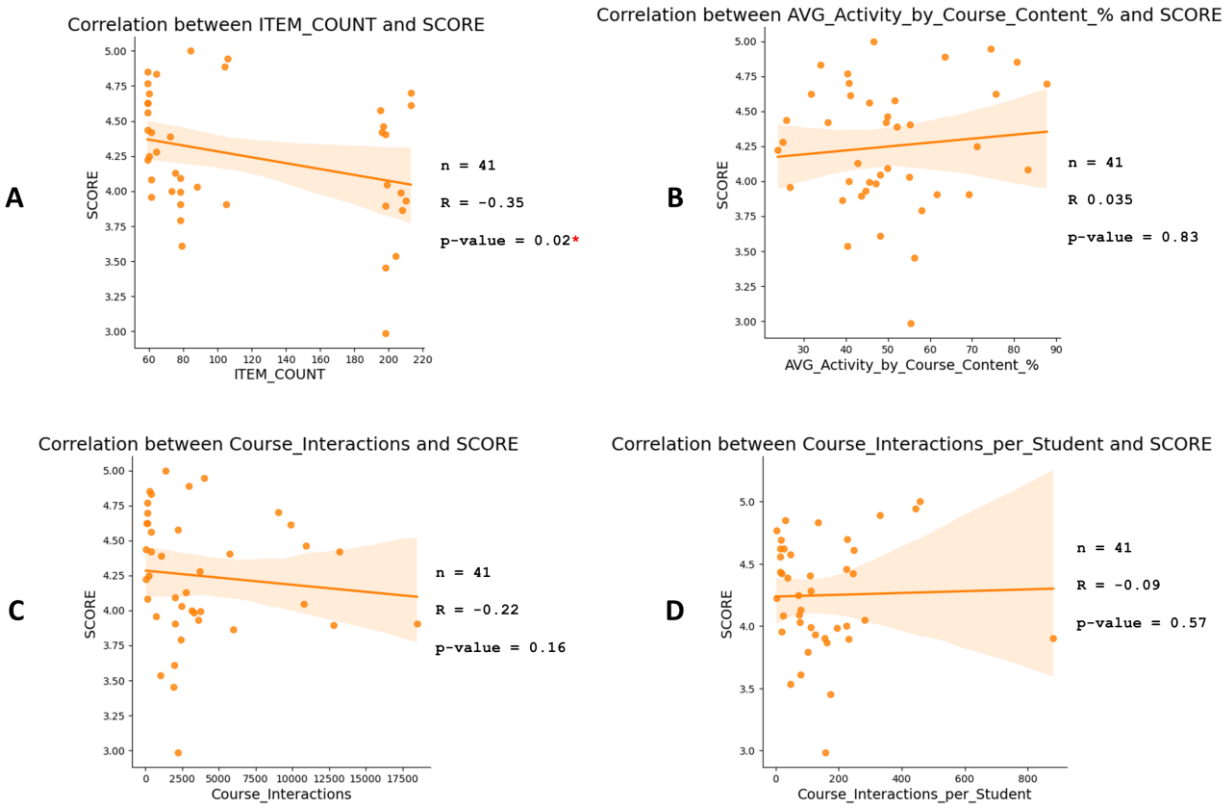


Figure 10. The correlation analysis between (A) item count, (B) average activity by course content, (C) course interactions, and (D) normalized course interactions per student and the score. A statistically significant (p-value < 0.05) difference is denoted with a red asterisk (*).

4. Discussion

This study provides a comprehensive examination of SAED's impacts on student achievement across a large, diverse university population. The analysis investigated the SAED effect on academic outcomes including pass rate, failure rate, prohibition rate, and scores, as well as LMS engagement metrics.

Initially, the courses had imbalanced SAED and control groups, with one course's control group about 8 times larger. To enable valid statistical comparisons, the data was randomly sampled to produce equal SAED and control groups within each course. The pass rate and score analysis then utilized this sampled data. SAED's differential effects were also analyzed across confounding factor subgroups.

The analysis of pass rate and student score data from over 2200 students across 105-course sections showed several key findings:

- The overall pass rate was very high at 98.1%, with low prohibition and failure rates of 0.1% and 1.4% respectively. This indicates most students completed their courses.

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- The average course section score was 4.3 out of 5.0, reflecting strong academic performance overall. Over half the students achieved A or A+ level scores.

Regarding the effect of SAED program participation on pass rates, the overall analysis found no significant difference compared to control conditions without SAED. Similarly, the follow-up differential analysis revealed no significant difference between SAED and the control group within each subgroup. Pass rates were uniformly high regardless of SAED participation or other variables examined.

Regarding the effect of the SAED program on students' scores, looking deeper into potential confounding factors, academic term, field of study, and campus location also showed no significant effects on scores between their subgroups. This implies that the broad subject matter, timing of the course, and physical learning environment do not substantially impact student scores either. However, significant effects were found for sex, faculty, and course type. Females scored higher than males, indicating an academic performance gap between the sex categories. The Nursing college had the highest scores, possibly reflecting differences in teaching methods, quality of students, or evaluation approaches between faculties. At the individual course level, a course in the Education college (DC-ET3) had the highest scores while a Humanities/Social Sciences course (PS-FS) had the lowest. This highlights the role of course-specific factors in influencing scores.

Within these subgroups, SAED had no impact on scores by academic term or field of study. However, differences emerged based on sex and campus, with SAED associated with higher scores for females, while the control had higher

scores for males. Similarly, SAED showed score benefits within Humanities/Social Sciences but lower scores in Law/Political Science versus control. This indicates that SAED effects may depend on the student population and faculty context. Overall, there was no significant difference in students' scores between SAED and the control group.

Similarly, prior studies have shown mixed impacts of some learning activities on course grades. Educational achievement is influenced by many interconnected factors and strategies. For instance, peer learning and flipped classroom techniques may significantly affect achievement [23,24]. In a study conducted by DeNeui [25] on the effect of using the Blackboard on the achievement of students (male and female), the study showed that the effect of the Blackboard on students' academic achievement in general was minimal and the results cannot be generalized. Indeed, relying solely on Blackboard for learning may lack a natural learning atmosphere, as the opportunities for direct contact between students and teachers are few, and therefore discussions are reduced because students need immediate, direct clarification of some questions and inquiries, and this slows down the learning process [26], and learning via Blackboard in this case is passive and may lead to negative educational outcomes for some students [27].

Despite some variability at the individual course level, statistically, there were no significant differences detected between SAED and control groups across Blackboard usage and interaction metrics when considering all courses collectively.

The lack of significant differences in student achievement and LMS engagement metrics between SAED and the "sole faculty-delivery" control groups can be interpreted as follows:

- The final course grades served as an unbiased measure to evaluate the effect of the SAED program on academic performance. However, grades are influenced by various factors, such as memorization, study effort, and grade distribution policies. Some courses may heavily weigh labs and practical skills (20-30% of the grade), which may not be directly influenced by e-learning delivery techniques.

- SAED program did not involve student interventions around modifying course content or presentation methods. The students solely assisted faculty with utilizing Blackboard, without actively influencing pedagogical design choices.

- While no significant differences were observed between SAED and control groups overall, the comparable outcomes could potentially indicate a positive influence of the SAED program. By actively training and utilizing students to support e-learning delivery, SAED may have helped participating courses achieve performance levels similar to the standard "sole faculty-delivery" counterparts.

Some faculty may be reluctant about student involvement in instructional delivery due to concerns around diluting quality, authority, or rigor. However, the SAED program was designed with proper training, restricted exam control, and faculty oversight to ensure students supplemented rather than replaced faculty teaching. The comparable academic performance and LMS engagement to the standard "sole faculty-delivery" approach suggests these collaborative approaches did not negatively impact educational outcomes. In contrast, student facilitation of platform engagement could promote faculty adoption. Additionally, active student

participation in e-delivery provides opportunities to engage in their learning process and develop teamwork and leadership skills essential for their academic and professional success.

The correlation between lower item counts and higher scores in 3.4.2 mirrors the "less is more effect" rule. This suggests that a high volume of superficial engagement, as represented by a higher number of LMS items, may impose a negative impact on learning outcomes such as exam scores. Additionally, the negligible correlation of other attributes with score suggests that interaction alone does not guarantee cognitive development. Davies and Graff (2005) declared that greater student interaction did not lead to an improvement in students' academic performance, however, students who failed in their courses tended to interact less frequently [28]. In contrast, John Fritz (2011) reported that students with lower grades (F and D) used Blackboard 39% less than students with higher grades [29]. A study conducted at Najran University in Saudi Arabia showed that using mobile learning and uploading the electronic version of the course content to Blackboard led to an increase in students' academic achievement and conversation skills [30]. In a study conducted at Princess Noura University in Saudi Arabia, the results showed that using the Blackboard increased the academic achievement of female students [31].

While providing initial evidence on SAED's impacts, the current study had some limitations that warrant discussion. The study relied on final course grades as the measure of academic achievement. Grades reflect many factors beyond just content mastery, like effort, attendance, and instructor grading tendencies. More direct content assessments could provide greater insight into learning. Faculty attitudes, teaching styles, and course designs likely differed between classes but were not directly analyzed. This may explain some course-level effects.

Overall, while this study provides initial evidence, further research with more controlled conditions, direct instructional evaluations, diverse institutions, larger samples, and additional outcome measures could help strengthen the breadth and generalizability of findings regarding SAED's efficacy. Exploring SAED solely with teachers lacking technology skills could provide more valuable insights.

5. Conclusions

This study evaluated the impacts of the SAED program through a rigorous analysis of academic achievement and Blackboard usage data from over 2,200 university students. A key strength was the comprehensive examination of achievement outcomes and engagement metrics across diverse student and course populations. This enhanced the generalizability of findings to the university context and allowed for nuanced interrogation of differential effects between relevant demographic and curricular subgroups. Employing appropriate statistical techniques and balancing sample sizes through randomized adjustment enabled valid comparisons between SAED and control conditions. Exploratory data analytics utilizing Python facilitated deep interrogation of results while accounting for confounders.

The high baseline pass rates and scores indicate most students completed courses regardless of SAED involvement. For student scores, SAED also did not have an overall significant effect. Some subgroup differences emerged, with SAED associated with higher scores for certain populations like females but lower scores for males. However, at the individual course level, results were mixed, with only 2 courses showing SAED score improvements and 3 favoring the control group.

The comparable overall performance between SAED and the "sole faculty-delivery" groups suggests SAED support approximated traditional instruction in providing equitable e-learning experiences, despite variability among subgroups. While

unable to definitively determine causality, the rigorous methodology lends credibility to evaluating this educational initiative's role in optimizing blended pedagogies. Nevertheless, directly measuring instructional quality remains necessary to validate SAED impacts on cognitive development.

Overall, provides an example of an educational practice that aims to advance technology-enabled pedagogy and contributes to transformation and greater equality in formal higher education contexts by actively engaging students in instructional delivery roles.

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Conflicts of Interest: “The authors declare no conflict of interest.”

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