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Psychological Mechanisms Linking Project-Based Learning to Sustainable Development Goals Awareness: The Mediating Roles of Self-Efficacy, Learning Motivation, and Flow Experience Perception

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Abstract

The study investigates the psychological mechanisms linking Project-Based Learning (PjBL) to students' awareness of the United Nations Sustainable Development Goals (SDGs) at Hanoi University of Science and Technology (HUST). Based on 192 valid responses, the study employs Partial Least Squares Structural Equation Modeling (PLS-SEM) to examine the proposed relationships and Analysis of Variance (ANOVA) to test differences across academic disciplines , the results reveal that self-efficacy has positive influence on student's awareness and knowledge and engagement with the SDGs. In contrast, learning motivation is found to affect only the evaluation dimension. Significant differences across academic disciplines were also identified in the three dimensions of SDG awareness. The study recommends enhancing the integration of SDGs into PjBL, fostering students' self-efficacy, aligning learning motivation with SDGs-related content, and providing faculty training. Furthermore, future research should explore external moderating factors - such as institutional policies, support from lecturers and enterprises, and the classroom environments - to strengthen the model's explanatory power.

Keywords: Higher education, project-based learning, psychological mechanisms, sustainable development goals, students' awareness.

1. Introduction

Since the United Nations adopted the 17 Sustainable Development Goals (SDGs) in September 2015 as a global call to eradicate poverty, protect the environment, and ensure prosperity by 2030, Vietnam – recognized by UNESCO as one of the first countries to commit to implementing this framework - has been encouraged to integrate these sustainability principles into educational curricula at all levels [1-2]. In this context, higher education (HE) not only plays a pioneering role in the implementation of the SDGs but also serves as a critical bridge connecting students, faculty, and industry partners. It thus contributes to raising awareness, sense of responsibility, and capacity to engage in decision-making and implement sustainable solutions in the future.

However, integrating SDGs into higher education presents a distinct pedagogical challenge. The challenges to achieving the SDGs are considered "wicked problems", complex and multi-dimensional issues that can not be solved rote memorization or passive lecture. To meaningfully internalize these goals, students require an active learning environment that fosters critical thinking, collaboration, and real-world problem solving. Thus, Project-Based Learning (PjBL) is particularly suitable for this purpose. PjBL has been recognized as an effective teaching strategy for stimulating learning motivation and comprehensively developing 21st-century skills, including collaboration, problem-solving, creativity, and critical thinking, while simultaneously supporting students in advancing the SDGs and meeting the growing demand for innovation in the training of high-quality human resources [3-4]. By engaging students in authentic, real-world tasks, PjBL narrows the gap between abstract sustainability concepts and their practical application, helping learners experience the interconnected nature of the SDGs firsthand.

The case of Hanoi University of Science and Technology (HUST) offers a particularly valuable context for examination. As Vietnam's leading technical university, HUST has historically emphasized strong engineering competencies. This makes the integration of "soft" sustainability-oriented mindsets into its intensive technical programs both necessary and complex. Although HUST has adopted several PjBL-based initiatives such as the Global Project-Based Learning in collaboration with Shibaura Institute of Technology (2016-2024) and the GREENUS project under the Erasmus+ program, existing reports on these programs have predominantly focused on general skill development, including teamwork, intercultural communication, and problem solving [5-8]. To date, there remains a significant research gap regarding both

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quantitative and qualitative of the psychological mechanisms underlying these educational experiences. Specifically, it is unclear how PjBL influences the internal cognitive mechanisms of HUST students and whether these mechanisms translate into awareness and knowledge, engagement, and evaluation of the SDGs.

To address this gap, this study explores the internal cognitive processes facilitated by PjBL. Drawing on educational psychology frameworks, we posit that the impact of PjBL is mediated by three key psychological mechanisms: self-efficacy (SE), learning motivation (LM), and flow experience perception (FEP) [9-12]. Consequently, the study aims to answer the following research questions :

1) How do the psychological outcomes of PjBL (SE, LM, FEP) impact HUST students' awareness and knowledge of the SDGs?
2) How do these psychological factors influence HUST students' level of engagement and evaluation in activities related to SDGs?
3) How does the effectiveness of these psychological factors vary among student groups from academic disciplines in HUST?

2. Literature Review

2.1. Project-Based Learning

PjBL is an active instructional method in which learners actively construct their knowledge and develop skills through the implementation of real-world projects. According to Thomas (2000), an activity can only be considered as PjBL when it meets five essential criteria: (1) the project serves as the central component of the curriculum; (2) it revolves around a motivation problem or driving question; (3) it involves constructive investigation; (4) it empowers students in learning process; (5) it reflects the practicality of the real world [13]. An additional perspective that complements this definition views PjBL is not only as a teaching strategy but also as a learning method rooted in John Dewey's "learning by doing" philosophy. Dewey argued that PjBL enables learners to apply language and thinking skills in real-world contexts, thereby solving problems or creating products in a meaningful way [14]. Similarly, Katz and Chard (2014) highlighted that PjBL fosters creative thinking, encourages students to ask questions, and enables them to access a variety of tools to solve problems [15].

From another perspective, Aksela and Haatainen (2019) summarized the core characteristics of PjBL as including constructive inquiry, autonomy, collaboration, reflection, and a clear goal orientation [16]. Notably, the elements of a driving question and a tangible artifact are considered indispensable components, aimed at concretizing learning outcomes through the creation of models, reports, videos, or technological products.

2.2. Sustainable Development and Sustainable Development Goals

The concept of sustainable development has emerged as a global strategic orientation aimed at a balancing economic growth, social equity, and environmental protection for the benefit of both present and future generations. It was first defined by the World Commission on Environment and Development in 1987 as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [17]. Building on this foundation, the United Nations General Assembly adopted the 2030 Agenda for Sustainable Development in 2015, introducing 17 SDGs covering three main pillars: economic, social, and environmental [1]. Each goal is further articulated through a set of quantitative and qualitative targets, enabling countries and organizations to systematically track and evaluate their progress.

2.3. The Psychological Mechanism of Project-Based Learning in Sustainability Education

Based on the framework of constructivist learning theory, especially John Dewey's philosophy of "learning by doing", which posits that genuine knowledge is constructed through experiential interaction with the environment rather than passive reception. Within this framework, PjBL works as a pedagogical intervention method that influences student outcomes not directly, but by activating specific psychological mechanisms. Integrating social cognitive theory, and self-determination theory with the empirical models of Chang *et al*. (2018) and Maoela *et al*. (2024), we propose that Self-Efficacy (SE), Learning Motivation (LM), and Flow Experience Perception (FEP) act as the critical cognitive mediators between the PjBL method and SDG awareness.

2.3.1. Project-based learning as a driver of psychological engagement

Unlike traditional instruction, PjBL places students in active roles. This environment is theoretically described and empirically proven to enhance psychological states through three distinct pathways as following:

1) Self-Efficacy through mastery experiences

According to Bandura's social cognitive theory, "mastery experiences" overcoming obstacles to succeed, this is the most potent source of SE [10]. PjBL inherently provides these experiences by allowing students to take ownership of their learning process, confront challenges, and witness the tangible outcomes of their efforts. Consistently, Chang *et al*. (2018) validated that within sustainability education, SE is not just a trait but a measurable outcome of project work, strongly predicting students' ability to persist in complex learning tasks [9].

2) Learnigh motivation through autonomy and task value

Self-determination theory suggests that intrinsic motivation flourishes autonomy and competence needs are met [11]. PjBL supports autonomy by allowing students to make choices about their learning path. Empirically, Shin (2018) demonstrates that motivation in PjBL is sustained because the "authentic" nature of the project increases the perceived task value, this makes students are more engaged when solving real problems rather than abstract exercises [18]. Chang *et al* (2018) also reinforce this, identifying that in PjBL, motivation is triggered when learners rely on their fondness for the activity itself to initiate learning actions, rather than external rewards [9]. The "real word" relevance of SDGs amplifies this intrinsic value.

3) Flow Experience through challenge and skill balance

Flow is a state of deep absorption where challenge matches skill [12]. PjBL fosters this by offering clear goals and immediate feedback. Chang *et al*. (2018) incorporate this into their assessment model, arguing that measuring the degree of "flow" (concentration, loss of self-consciousness) is essential to understanding the internal learning effectiveness of the project [9].

2.3.2. From psychological states to sustainable development goals awareness

The relationship between the psychological states fostered through PjBL and resulting students' awareness of SDGs is not linear but multifaceted. Building on the outcome dimensions proposed by Maoela *et al.* (2024): awareness and knowledge (AK), engagement (EN), and evaluation (EV). We posit that SE, LM, and FEP collectively serve as the cognitive and affective drivers for these outcomes. This theoretical foundation provides the rationale for the relationship proposed in our research model as follows.

1) Enhancing awareness and knowledge:

The complexity of SDGs requires deep cognitive processing. According to social cognitive theory, students with high SE are less likely to view complex global problems as threats, thereby fostering an openness to learn and absorb new knowledge [10]. Similarly, flow theory suggests that the deep concentration inherent in flow states allows for "deep learning" rather than surface memorization, facilitating a comprehensive understanding of the SDGs [19]. Furthermore, Chang *et al*. (2018) indicate that intrinsic LM drives students to actively seek information, directly enhancing their awareness levels [9].

2) Driving active engagement:

Engagement goes beyond mere attendance, it requires active participation. Self-determination theory posits that motivation as a sense of competence (SE) are the primary engines of behavioral engagement [11]. When students feel capable and intrinsically motivated by the PjBL task, they are more likely to voluntarily participate in SDG-related activities. Additionally, the positive reinforcement from flow experiences creates a loop where students want to re-engage with the content to replicate that optimal state [19].

3) Fostering positive evaluation

Evaluation reflects the students' attitude and value judgment regarding the SDGs. Psychological engagement suggests that positive internal experiences such as feeling competent (SE), enjoying the learning process (LM), or being immersed (FEP) lead to positive attributions toward the subject matter [20]. Students who experience PjBL as psychologically rewarding are theoretical predicted to ascribe higher importance and value to the SDGs, viewing them not as abstract burdens but as meaningful goals.

3. Research Model and Research Method

3.1. Research Model

While PjBL involves elements like the number of hours students participate in PjBL, the quality of the PjBL projects, the type of PjBL, etc., Its educational value is fundamentally defined by the internal learning effectiveness it triggers in students. Drawing on the validated assessment framework by Chang *et al*. (2018), the research team selected and identified three psychological dimensions: SE, LM, and FEP [9].

In this study, rather than measuring the physical parameters of the projects, we adopt the view that SE, LM, and FEP are the proximal outcomes of successful PjBL implementation. Specifically, PjBL facilitates a "learning by doing" environment that fosters immersion (FEP), builds confidence (SE), and stimulates intrinsic interest (LM). These psychological states serve as the driving forces that influence the dependent variables adopted from the research by Maoela *et al*. (2024): awareness and knowledge, engagement, and evaluation (EV) [21]. Thus, the model posits that PjBL impacts SDG perception indirectly through these psychological mechanisms.

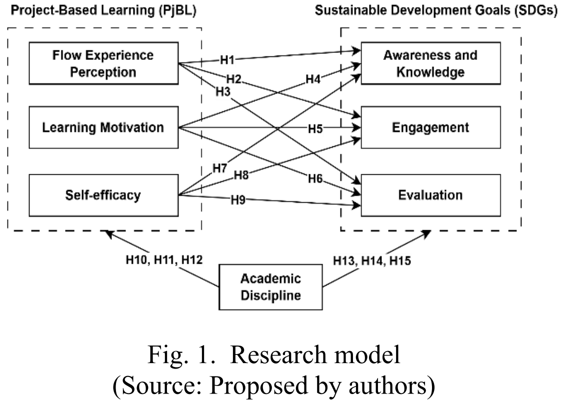

Fig. 1. Research model
(Source: Proposed by authors)

Based on the proposed model, the research team formulated the following hypotheses.

H1: Flow experience perception has a positive impact on students' awareness and knowledge of the SDGs.

H2: Flow experience perception has a positive impact on students' engagement with the SDGs

H3: Flow experience perception has a positive impact on students' evaluation of the SDGs.

H4: Learning motivation has a positive impact on students' awareness and knowledge of the SDGs.

H5: Learning motivation has a positive impact on students' engagement with the SDGs.

H6: Learning motivation has a positive impact on students' evaluation of the SDGs

H7: Self-efficacy has a positive impact on students' awareness and knowledge of the SDGs.

H8: Self-efficacy has a positive impact on students' engagement with the SDGs

H9: Self-efficacy has a positive impact on students' evaluation of the SDGs

H10: There is a significant difference in students' flow experience perception across different academic disciplines when engaging in PjBL.

H11: There is a significant difference in students' learning motivation across different academic disciplines when engaging in PjBL.

H12: There is a significant difference in students' self-efficacy across different academic disciplines when engaging in PjBL.

H13: There is a significant difference in students' awareness and knowledge of the SDGs across different academic disciplines.

H14: There is a significant difference in students' engagement with the SDGs across different academic disciplines.

H15: There is a significant difference in students' evaluation of the SDGs across different academic disciplines.

3.2. Research Methodology

3.2.1. Scale development

The measurement scales used in the model were primarily adapted from previous related studies and evaluated using SmartPLS and SPSS software. Specifically, flow experience perception was measured by four observed variables [9]. Learning motivation was measured with five observed variables [22], while self-efficacy was measured by eight observed variables [9]. The constructs of awareness and knowledge of SDGs, engagement, and evluation were each measured using 17 observed variables, adapted from Maoela *et al.* [21].

To ensure content validity, the observed variables were reviewed through a qualitative study involving in-depth interviews with two experienced educational researchers. Subsequently, exploratory factor analysis (EFA) was conducted to refine and adjust the measurement model. Most items were evaluated using a 5-point Likert scale, where 1 indicates "strongly disagree" and 5 indicates "strongly agree".

3.2.2. Reliability and validity analysis of the scale

Table 1. Results of scale reliability assessment

Factor	Cronbach's Alpha	rho_A	CR	AVE
FEP	0.813	0.883	0.870	0.626
SE	0.907	0.915	0.924	0.604
LM	0.884	0.885	0.915	0.683
AK	0.964	0.966	0.967	0.637
EN	0.973	0.974	0.975	0.698
EV	0.962	0.971	0.965	0.622

All factors in the model demonstrated high internal consistency, with Cronbach's Alpha, rho_A, and Composite Reliability (CR) values exceeding the threshold of 0.7 (Table 1). Additionally, all Average Variance Extracted (AVE) values were greater than 0.5 (Fig. 2), confirming that the observed variables effectively measured the underlying constructs and that the scale demonstrated adequate convergent validity.

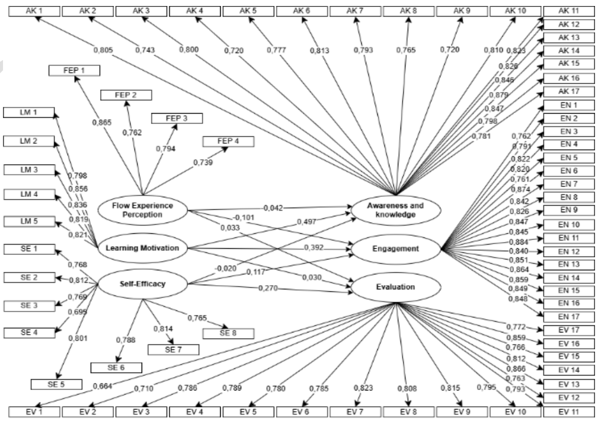

Fig. 2. SEM model
(Source: Authors' own work)

Furthermore, the model showed that most of the observed variables had factor loadings greater than 0.5, indicating sufficient convergent capacity. These results suggest that the observed variables consistently and reliably represent the latent constructs in the research model.

Table 2. Results of scale reliability assessment

Factor	Cronbach's Alpha	rho_A	CR	AVE
FEP	0.813	0.883	0.870	0.626
SE	0.907	0.915	0.924	0.604
LM	0.884	0.885	0.915	0.683
AK	0.964	0.966	0.967	0.637
EN	0.973	0.974	0.975	0.698
EV	0.962	0.971	0.965	0.622

Based on the data presented in Table 2, all Heterotrait-Monotrait Ration (HTMT) values were below the threshold of 0.85, indicating that the factors exhibit clear conceptual distinctions and satisfy the criterion for discriminant validity.

Table 3. Results of discriminant validity testing

Factor	(1)	(2)	(3)	(4)	(5)	(6)
FEP (1)						
AK (2)	0.292					
SE (3)	0.738	0.472				
EN (4)	0.244	0.672	0.417			
EV (5)	0.244	0.327	0.241	0.363		
LM (6)	0.753	0.328	0.794	0.349	0.324	

3.2.3. Sample and data collection

The survey was conducted at HUST with the aim of capturing students' perspectives across a range of academic disciplines. To effectively reach these student groups, the research team asked the supports from lecturers who are in charge of various courses, including general education, foundational major course, core major courses, and supplementary courses (e.g., soft skills, applied psychology, business culture and entrepreneurship, and introduction to management), to distribute the survey link.

Data collection was carried out from March 30 to April 12, 2025, yielding a total of 331 responses. To ensure data quality and reliability, a two step screening procedure was implemented. First, students who reported prior participation in PjBL were excluded, as they fell outside the study's target population. Second, the dataset was cleaned by removing responses with excessively short completion times and those showing straight-lining behavior. After applying these criteria, 192 valid and reliable responses remained for analysis, ensuring that the results reflect the authentic perceptions of students with actual PjBL experience.

The demographic analysis showed that 66% (n = 126) of respondents were male and 34% (n = 66) were female students. In terms of academic year, the majority were second-year students, accounting for 55% (n = 105), followed by third-year students (32%, n = 62), fourth-year (7%, n = 14), first-year (4%, n = 7), and fifth-year students (2%, n = 4).

Regarding academic disciplines, 27% (n = 53) of the respondents were from the field of Economics and Management, 23% (n = 44) from Electrical and Electronic Engineering, 17% (n = 32) from Information and Communication Technology, 14% (n = 27) from Educational Sciences and Technology, 8% (n = 15) from Chemistry and Life Sciences, and 11% (n = 21) from Mechanical Engineering.

In terms of prior exposure to PjBL, 67% (n = 128) of students had participated in foundation major courses with a PjBL orientation, 46% (n = 88) in general education courses, 39% (n = 75) in core major courses, and 43% (n = 83) in supplementary skill-based courses.

3.2.4. Data analysis method

The data were processed through multiple stages. First, descriptive statistics and Kruskal-Wallis test were employed to assess the influence of demographic variables, using the following significance thresholds: p was lower than 0.01 (highly significant difference), p was lower than 0.05 (significant), p was equal to or greater than 0.05 (not significant) [23].

Exploratory Factor Analysis (EFA) was then conducted with the following criteria: KMO value was higher than 0.7; the significance level of Bartlett's test was lower than 0.05; factor loadings > 0.5; Eigenvalues ≥ 1; and total variance explained was at least 60% [24].

Subsequently, the Partial Least Squares Structural Equation Modelling (PLS-SEM) was applied to test hypotheses H1 through H9. The model was evaluated using several criteria: Cronbach's Alpha, rho_A, and Composite Reliability (CR) values above 0.7; Average Variance Extracted (AVE) above 0.4 (acceptable for exploratory research); factor loadings greater than 0.5; HTMT values below 0.85; *VIF* values below 4; and the coefficient of determination (R^2) [25-27].

Hypotheses H10 to H15 were examined using One-Way ANOVA. Levene's test was employed to assess the homgeneity of variances: when p was greater than 0.05, equal variance between groups was assumed (standard ANOVA was used); when p was lower than 0.05, variances were heterogeneous (using Welch ANOVA analysis). In ANOVA analysis (in case of homogeneous variance), if p was lower than 0.05, there was a significant difference between groups; if *Sig*. was greater than 0.05, there was no significant difference between groups. In Welch ANOVA analysis (in case of heterogeneous variance), if p value lower than 0.05, there was a significant difference between groups; if *Sig.* value was greater than 0.05, there was no significant difference between groups [28].

Finally, Harman's single-factor test was conducted to assess common method bias. The results showed that the first factor explained only 34,855% of the total variance, indicating that common bias was not a significant concern.

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4. Results

4.1. The Current Status of Project-Based Learning and Sustainable Development Goals at HUST

In Fig. 3, the percentage of students who experienced PjBL related to the SDGs across different course categories and disciplines is presented as follows.

(1) In general education courses, there was considerable variation among disciplines. Specifically, students in Mechanical Engineering had the highest participation rate (39.58%), while those in Technology had the lowest (11.48%).

(2) In foundational disciplinary courses, the variation was moderate. Electrical and Electronics Engineering recorded the highest rate (43.59%), and Mechanical Engineering the lowest (22.92%).

(3) In core disciplinary courses, substantial variation was observed. The highest rate was found in Information and Communication Technology (27.87%), and the lowest in Electrical and Electronics Engineering (8.97%).

(4) In supplementary courses, the distribution was relatively even across disciplines. Electrical and Electrical Engineering had the highest percentage (25.65%), while Economics and Management recorded the lowest (20.39%).

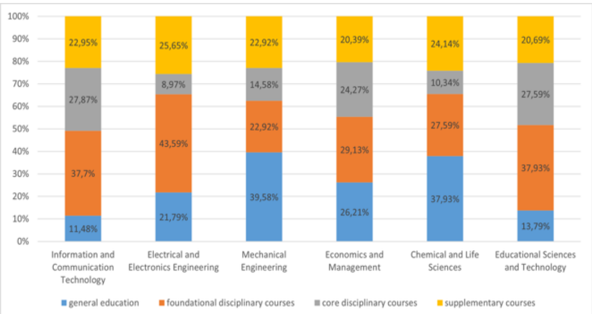

Fig. 3. Percentage of PjBL learning on SDGs in subjects across disciplines

4.1.1. Flow experience perception in project-based learning courses

The Kruskal–Wallis test was conducted to examine differences in students' flow experience perception across academic disciplines, gender, and academic level. The results revealed a statistically significant difference in the level of concentration across academic disciplines ($p = 0.048 < 0.05$). This finding suggests that students from disciplines such as Mechanical Engineering or Electrical and Electronic Engineering may experience a deeper sense of concentration, potentially due to the hands-on and practical nature of their PjBL activities. However, no significant differences were found regarding gender or academic level ($p > 0.05$) (Appendix-Table A2).

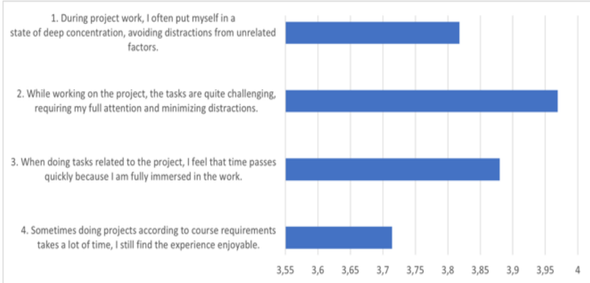

Fig. 4. Mean value of flow experience perception in PjBL courses

Fig. 4 illustrates that students generally expressed positive perceptions of their PjBL experiences, with mean scores ranging from 3.714 to 3.969 and standard deviations between 0.787 and 0.884. Observed Variable 2 recorded the highest mean score (3.969 ± 0.792), indicating a high level of concentration during project implementation. In contrast, Observed Variable 4 had the lowest mean score (3.714 ± 0.884), suggesting that time management remains a challenge for many students.

4.1.2. Self-efficacy in project-based learning courses

Regarding self-efficacy, the Kruskal–Wallis test results indicated that students' confidence levels were generally consistent across gender and academic levels ($p > 0.05$). However, a significant difference was found among students from different disciplines regarding Item 2 ($p = 0.007 < 0.01$). This indicates that certain student groups in specific disciplines are particularly confident in their ability to complete project outcomes or final assignments by self-adjusting and applying effective, optimized learning strategies (Appendix-Table A3).

Overall, as shown in Fig. 5, students expressed relatively consistent opinions and confidence in their self-efficacy. Item 4 recorded the highest mean score (4.016 ± 0.755). In contrast, item 3 received a lower score compared to the others (3.760 ± 0.853). This suggests that although students may encounter unfavorable learning conditions, they do not always find suitable learning methods to complete assignments.

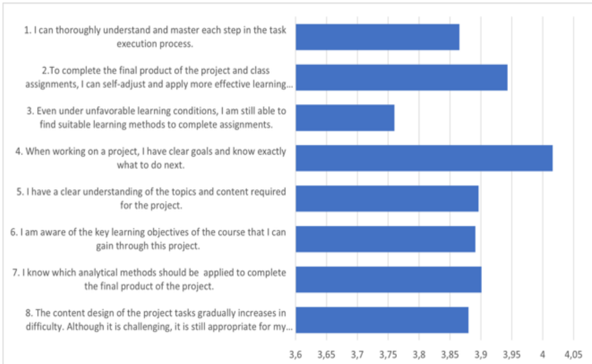

Fig. 5. Mean value of self-efficacy in PjBL courses

4.1.3. Learning motivation in project-based learning courses

The Kruskal–Wallis analysis for learning motivation showed no significant differences across gender, student level, or disciplinary field ($p > 0.05$). This suggests that the high level of motivation is relatively uniform among the student population (Appendix-Table A4).

Fig. 6 shows that most students exhibit a very high level of learning motivation when participating in PjBL classes related to SDG content (ranging from 3.865 to 4.031). The highest mean value is observed in Variable 2: "I take additional PjBL classes to improve my current professional knowledge and skills" (4.031 ± 0.744), indicating that students are eager to enhance their skills and knowledge relevant to their field through PjBL participation.

Fig. 6. Mean value of learning motivation in PjBL courses

4.1.4. Awareness and knowledge of sustainable development goals

Regarding students' awareness and knowledge, the statistical analysis revealed significant differences across specialized disciplines for the majority of the goals. Specifically, clear distinctions were found for SDG3, SDG9, SDG11, SDG12, and SDG16, as well as significant differences for SDG1, SDG2, SDG8, SDG10, SDG14, and SDG15 ($p < 0.05$) (Appendix-Table A5).

As presented in Fig. 7, SDG2 has the lowest average value (3.339 ± 1.128), indicating diverse viewpoints among students, with differing levels of awareness about the issue of zero hunger. The highest is SDG4 (Quality Education) (3.906 ± 0.899), showing a clear awareness among students regarding this goal.

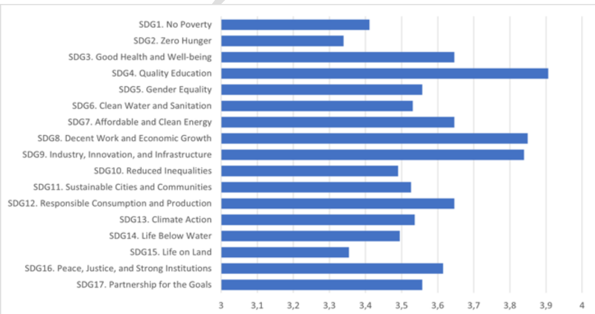

Fig. 7. Mean value of awareness and knowledge of SDGs

4.1.5. Engagement in sustainable development goals

The Kruskal-Wallis test on student engagement highlighted significant disciplinary differences for SDG1, SDG2, SDG3, SDG8, SDG10, SDG12, SDG14, SDG15, and SDG17. Furthermore, a significant difference based on educational levels was observed specifically in SDG 7 and SDG 17 ($p < 0.05$) (Appendix-Table A6).

Fig. 8 indicates that SDG2 has the lowest average (3.417 ± 1.141), indicating diverse student perspectives and varying levels of participation in the issue of zero hunger. The highest is SDG3 (3.854 ± 1.048), showing positive awareness among students regarding this goal, although there is still a certain degree of dispersion in opinions.

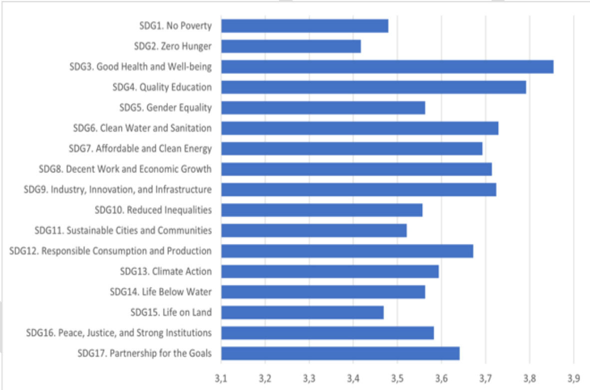

Fig. 8. Mean value of engagement in SDGs

4.1.6. Evaluation of sustainable development goals

Finally, regarding the evaluation of SDGs, the analysis showed significant disciplinary differences for SDG1, SDG2, SDG13, and SDG16 ($p < 0.05$). Additionally, gender differences were also evident, with a clear difference observed in SDG1 and a significant difference in SDG2 (Appendix-Table A7).

According to Fig. 9, SDG2 has the lowest average (3.094 ± 0.857), indicating that students have diverse perspectives, with varying levels of evaluation on the issue of eradicating hunger. The highest value is for SDG3 (3.670 ± 0.761), indicating a clear understanding among students when evaluating this goal.

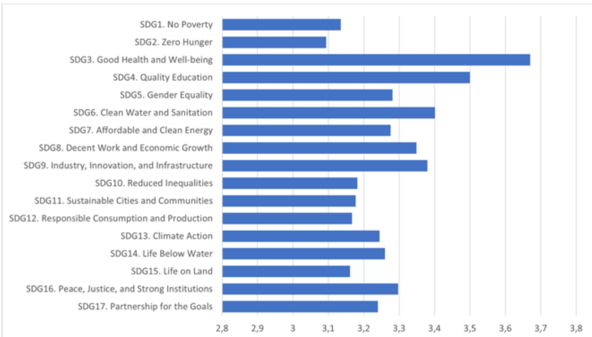

Fig. 9. Mean value of evaluation of SDGs

4.2. Exploratory Factor Analysis

After testing the reliability using Cronbach's Alpha, rho_A, CR, and AVE, an Exploratory Factor Analysis (EFA) was conducted to explore the latent structure of the observed variables and assess the construct validity of the measurement scale (Table 9). Bartless test in EFA indicated that the variables were correlated (*Sig.* = 0.000). *KMO* value of 0.941 (> 0.7) confirming the appropriateness of EFA. The analysis results show that, with Eigenvalue greater than1, using Principal Axis Factoring method and Promax rotation with Kaiser normalization, extracted 3 factors from 21 observed variables, explaining a cumulative variance of 62.162% (>50%). After removing four items with low factor loadings (<0.5), the remaining 17 items were grouped into three factors. The final result showed a cumulative variance of 64.333%, a *KMO* value of 0.933 (> 0,5), and a significant Bartlett's test (*Sig.* < 0.05).

Table 9. Results of exploratory factor analysis

	Factor		
	1	2	3
SE3	0.915		
SE2	0.755		
SE4	0.744		
SE1	0.738		
SE3	0.709		
SE5	0.706		
SE1	0.646		
SE1	0.578		
LM4		0.819	
LM4		0.814	
LM2		0.748	
LM3		0.747	
LM1		0.739	
FEP2			0.758
FEP6			0.757
FEP5			0.737
FEP4			0.725
Total	8.517	1.274	1.146
% of Variance	50.100	7.493	6.740
Cumulative %	50.100	57.593	64.333

4.3. Hypothesis Testing

4.3.1. Hypothesis testing from H1 to H9

The analysis results show that the Variance Inflation Factor (VIF) ranges from 1.898 to 2.255 (lower than 3), indicating that multicollinearity does not significantly affect the estimation results. The coefficient of determination (R^2) falls within the range of 0.099 to 0.209, meaning that the independent variables in the model can explain 9.9% to 20.9% of the varience across the dependent variables. Detailed estimation results are presented in Table 10.

Table 3. Estimation results

2	β	Std.D	*t*-value	*p*-value
H1	-0.037	0.089	0.409	0.683
H2	-0.091	0.107	0.854	0.393
H3	0.035	0.113	0.308	0.758
H4	-0.053	0.118	0.449	0.653
H5	0.103	0.120	0.856	0.392
H6	0.271	0.102	2.662	0.008*
H7	0.520	0.116	4.468	0.000*
H8	0.388	0.107	3.637	0.000*
H9	0.026	0.138	0.188	0.851

In Table 3, it is shown that self-efficacy has a direct impact on awareness and knowledge (H7, β = 0.520; *p*-value = 0.000), and on engagement (H8, β = 0.388; *p*-value = 0.000). Learning motivation has a direct impact on the evaluation of SDGs (H6, β = 0.271; *p* = 0.008). From this, it can be stated that hypotheses H6, H7, and H8 are accepted. However, hypotheses H1, H2, H3, H4, H5, and H9 are rejected because the *p*-values of these hypotheses do not meet the required threshold ($p > 0.05$).

4.3.1. Hypothesis testing from H10 to H15

Based on the results of Levene's Test in Table. 4, the factors flow experience perception (*Sig.* = 0.006), awareness and knowledge (*Sig.* = 0.013) show that the variances are not homogeneous (*Sig.* < 0,05). In contrast, the factors self-efficacy (*Sig.* = 1.186), learning motivation (*Sig.* = 0.464), engagement (*Sig.* = 0.074), and evaluation (*Sig.* = 0.314) exhibited homogeneity of variances (*Sig.* > 0.05).

Table 4. Levene's Test

	F	df1	df2	*Sig.*
FEP	3.348	5	186	0.006*
SE	1.474	5	186	0.200
LM	0.928	5	186	0.464
AK	2.962	5	186	0.013*
EN	2.050	5	186	0.074
EV	1.194	5	186	0.314

Table 5. Welch ANOVA analysis

	F	df1	df2	*Sig.*
FEP	2.250	5	70.471	0.059
AK	3.832	5	66.383	0.004*

Continuing to observe the factors of flow experience perception, awareness and knowledge in Welch ANOVA analysis, the results showed that awareness and knowledge had significant differences between student groups from different disciplines (*Sig.* < 0.05). Meanwhile, flow experience perception had no significant difference between student groups (*Sig.* > 0.05).

In the results of ANOVA analysis (Appendix-Table A8), learning motivation showed no significant differences between among student groups across disciplines (*Sig.* > 0.05). However, self-efficacy, engagement, and evaluation all showed significant differences among students from different disciplines (*Sig.* < 0.05).

From the results of Welch ANOVA and ANOVA analysis, the significant difference between student groups was shown through descriptive analysis in Appendix-Table A9: (1) Students from *Chemistry and Life Sciences* exhibited the highest level of self-efficacy (4.042 ± 0.408). (2) In terms of awareness and knowledge, engagement, and evaluation of the SDGs, students in *Mechanical Engineering* scored the highest, with respective mean scores of (3.966 ± 0.711), (3.966 ± 0.745), (3.496 ± 0.466). (3) In contrast, students from Information and Communication Technology reported the lowest mean scores across all these dimentions: AK (3.123 ± 0.935), EN (2.984 ± 1.159), EV (2.984 ± 1.159), and SE (3.637 ± 0.629).

5. Discussion

The research findings confirm that self-efficacy positively influences student’s awareness and knowledge of the SDGs, as well as their level of engagement in SDG-related activities. This result aligns with Bandura's self-efficacy theory, which asserts that when individuals who believe in their own abilities are more likely to engage actively and persist in learning tasks and related activities [29]. This empirical result also validates our theoretical proposition in section 2.3.1 that PjBL acts as a generator of 'mastery experiences.' By successfully navigating the open-ended challenges of project work, students build the specific confidence required to engage with complex, multi-dimensional issues like the SDGs, effectively overcoming the psychological barrier of 'wicked problems. However, self-efficacy was not found to significantly influence student’s evaluation of SDGs (thus, Hypothesis H9 is rejected). A possible explanation is that evaluation represents a broader cognitive judgement that may not be directly tied to one’s perception of personal control or task-specific competence.

Secondly, learning motivation was found to significantly influence students’ evaluation of the SDGs, but did not have a significant effect on their awareness and knowledge (rejecting H4) or engagement (rejecting H5). These results suggest that while motivation may lead students to develop more favourable attitudes toward the SDGs, it is not sufficient to translate into deeper understanding or active participation. From a theoretical perspective, this suggests that while the “authentic value” of PjBL tasks (as noted by Shin, 2018) is sufficient to shape students' positive attitudes and valuation of the SDGs (EV), it may not be strong enough to drive active behavioural change (EN) or deep cognitive processing (AK) without clearer guidance [18]. This indicates that intrinsic motivation in this context is largely appreciative rather than action oriented.

Thirdly, the perceived flow experience mediated by PjBL was not found to exert a significant influence on students' AK, EN, or EV of the SDGs. This finding stands in contrast to the theoretical expectation derived from Flow Theory (section 2.3.1), which posits that immersion facilitates deep learning. The disconnection likely stems from the nature of the 'flow' experienced. In engineering PjBL, students may achieve flow states while solving *technical* problems (e.g., coding, debugging, assembling models) rather than engaging with the *sustainability* content itself. Consequently, the cognitive absorption is directed toward the technical artifact, leaving the SDG dimension peripheral. This suggests that technical immersion does not automatically transfer to sustainability awareness unless the two are inextricably linked in the project design.

Fourthly, ANOVA analysis and descriptive statistics revealed differences ranging from significant to substantial among students from different academic disciplines in terms of their awareness, engagement, and evaluation across most SDGs. Additionally, notable differences were observed by gender and educational level, particularly in relation to SDG1, SDG2, SDG7, and SDG17. Among the academic disciplines, students in Mechanical Engineering reported the highest levels of awareness, engagement, and evaluation of the SDGs. In contrast, students in Information and Communication Technology exhibited the lowest levels across all three dimensions. These disparities may reflect differences in curriculum design or the degree of natural alignment between disciplinary content and the SDGs. For instance, Mechanical Engineering programs may more readily incorporate projects related to clean energy (SDG7) or sustainable infrastructure (SDG9) [30], whereas ICT curricula are often more abstract or technical-focused, lacking direct SDG integration. Notably, students in Chemistry and Life Sciences demonstrated the highest levels of self-efficacy. This may be attributed to the hands-on and applied nature of their training, which is often directly linked to global health and environmental issues. Their participation in projects focused on areas such as green product development or clean water initiatives (e.g., SDG6) may contribute to a heightened sense of competence and confidence [31].

Finally, a critical finding of this study is the relatively low coefficients of determination (R^2 ranging from 9.9% to 20.9%). This low explanatory power does not invalidate the significant impact of the psychological variables identified. Furthermore, it provides a crucial insight: internal psychological factors alone are insufficient to explain the full spectrum of SDG awareness. This result strongly suggests that the majority of the variance is likely explained by external and structural factors that were outside the scope of this study. As suggested by the disciplinary differences found in our ANOVA analysis, factors such as institutional policies, the degree of faculty support, curriculum design differences across majors, learning environment, and the availability of enterprises partnerships likely play a much larger role. The absence of qualitative data (e.g., in-depth interviews) in this study's design, a methodological limitation noted by our team research. This limits a deeper exploration of why these external factors are so impactful or how they operate (e.g., why flow failed to show impact in the ICT discipline). This lack of qualitative insight helps to explain the remaining unexplained variance and the resulting low R^2. Therefore, the low R^2 is not a failure of the model, but a finding that highlights the necessity for future research to employ mixed-method approaches, moving beyond student-centric variables, and incorporates these external moderating factors to build a more comprehensive explanatory model.

6. Conclusion and Recommendation

6.1. Conclusion

This study explored the psychological mechanisms through which PjBL influences students' perceptions of the SDGs within a technical university context. By evaluating the mediating roles of SE, LM, and FEP, the study offers empirical insights into the cognitive processes underlying PjBL effectiveness. Based on data collected from 192 valid survey responses, and utilizing PLS-SEM and ANOVA analyses, the key findings are as follows:

1) SE positively influences students' awareness, knowledge, and engagement with the SDGs;
2) LM significantly affects students' EV of the SDGs but does not have a notable impact on their awareness or engagement;
3) FEP through PjBL does not significantly influence any SDG-related outcomes, highlighting the need to improve the interaction of SDG content into project design;
4) Disciplinary differences are evident: students in Mechanical Engineering reported the highest levels of AK, EN, and EV, while those in Information and Communication Technology showed the lowest. Additionally, students from Chemistry and Life Sciences demonstrated the highest levels of SE.

Despite these insights, several limitations must be acknowledged. First, the low R^2 values, while interpreted in the Discussion as a key finding regarding the necessity of external factors, also indicate that the current model has not yet captured the full complexity of SDG awareness drivers. Second, although the sample distribution reflects the varying scales of academic disciplines at HUST, the relatively small sample sizes in certain subgroups (e.g., Materials Science, Mathematics and Informatics, Foreign Languages, and Physics) may limit the statistical robustness of comparative analyses. Furthermore, the absence of qualitative data (e.g., in-depth interviews) prevents a deeper explanation for why certain mechanisms failed to show impact or why disciplinary differences were observed.

Future research should therefore consider extending the sample size to ensure balanced statistical power across all subgroups and employ mixed-method approaches to explore the nuanced contexts of PjBL implementation.

6.2. Recommendations

Based on the findings, the research team proposes several recommendations to enhance the effectiveness of PjBL in delivering content related to the SDGs.

1) *Strengthen SDG integration in project design*

Project designs should explicitly and transparently link to at least one specific SDG or a cluster of SDGs to ensure clear purpose and practical relevance. This approach will facilitate students' recognition of the connections between project tasks and broader sustainable development objectives, thereby promoting SDG-oriented flow experiences:

- *Develop targeted guiding questions*

  Rather than generic prompts, projects should commence with challenging questions directly tied to an SDG. For instance, "How can AI be applied to enhance waste management systems in urban areas of Vietnam?" (relating to SDGs11 and SDGs12).

- *Provide meaningful feedback*

  Instructors should incorporate feedback mechanisms that address not only technical aspects but also the project's contributions to SDGs, thereby sustaining student focus and reinforcing these linkages.

- *Diversify project outputs*

  Encourage students to produce reflective deliverables, such as blogs or social impact reports, to foster introspection and transform experiences into deeper insights.

2) *Strengthening self-efficacy and learning motivation*

- *Bolstering self-efficacy*

  Research indicates that self-efficacy positively influences students' awareness and engagement with SDGs. Instructors should promote this through small-scale, feasible projects that enable early successes, coupled with timely and constructive feedback to build student confidence.

- *Linking learning motivation to SDGs*

  Study findings reveal that learning motivation impacts evaluation but not awareness or engagement. Therefore, motivation should be stimulated by associating SDG content with incentives, such as bonus points, SDG-related certifications, or aligning SDG learning objectives with students' personal goals, thereby enabling them to explore and derive personal meaning from SDG-related work.

3) *Developing project strategies tailored to each specific area of expertise*

PjBL strategies need to be adapted to the specific context of each academic discipline to maximize their effectiveness:

- For students in Chemistry, projects focusing on recycling and green chemistry are likely to generate stronger engagement and resonance;
- For students in Information and Communication Technology, customized solutions involving AI applications for sustainable urban development can be designed;
- Interdisciplinary projects involving fields with varying levels of awareness of the SDGs can foster peer learning and broaden students' perspectives.

4) *Instructor training*

Instructors play a pivotal role in SDG integration. Comprehensive training programs should be established to equip them with the necessary knowledge and tools for meaningfully embedding SDG themes into PjBL courses and assessment processes;

In addition to the above recommendations, several future research directions should be considered to broaden insights and strengthen the integration of PjBL with the SDGs.

1) *Broaden and Diversify Future Samples*

Future research should include students from various academic levels and underrepresented disciplines such as Materials Science, Mathematics and Informatics, Foreign Languages, and Physics to enhance the representativeness and generalizability of findings.

2) *Employ Mixed-Method Approaches*

Future research should adopt a mixed-method design. The current study relied solely on quantitative data, which allows the identification of relationships but not to understand the reasons behind them. For example, although the findings showed that Flow did not influence SDG awareness and motivation did not lead to higher engagement, the data could not explain why these patterns appeared. Incorporating qualitative methods such as in-depth interviews would help clarify these issues by revealing contextual factors related to curriculum, teaching practices, or student perceptions that the present model could not capture.

3) *Incorporate External Moderating Factors*

To increase the explanatory power of the research model, future studies should account for external factors such as institutional policies (e.g., the level of support from the school/faculty leadership), support from instructors (e.g., personalized mentorship), enterprises partnership (e.g., the degree of involvement in real-world SDG projects), and the learning environment (e.g., providing appropriate facilities to facilitate SDG-related learning activities), which may significantly influence students' engagement with the SDGs.

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Appendix

Table A1. 17 Sustainable Development Goals is listed in the below table.

SDG1	**SDG2**	**SDG3**	**SDG4**
No poverty	Zero hunger	Good health and well-being	Quality education

SDG5	**SDG6**	**SDG7**	**SDG8**
Gender equality	Clean water and sanitation	Affordable and clean energy	Decent work and economic growth

SDG9	**SDG10**	**SDG11**	**SDG12**
Industry, innovation and infrastructure	Reduced inequalities	Sustainable cities and communities	Responsible consumption and production

SDG13	**SDG14**	**SDG15**	**SDG16**	**SDG17**
Climate action	Life below water	Life on land	Peace, justice and strong institutions	Partnerships for the goals

Table A2. Kruskal-Wallis test on flow experience perception in PjBL courses

No.	Std.D	Kruskal-Wallis test (*p*-value)		
		Gender	Level	Discipline
1	0.833	0.529	0.518	0.048*
2	0.792	0.394	0.796	0.442
3	0.787	0.431	0.577	0.115
4	0.884	0.971	0.926	0.564

Table A3. Kruskal-Wallis test on self-efficacy in PjBL courses

No.	Std.D	Kruskal-Wallis test (p-value)		
		Gender	Level	Discipline
1	0.747	0.945	0.820	0.054
2	0.781	0.775	0.218	0.007*
3	0.853	0.717	0.151	0.086
4	0.755	0.107	0.969	0.216
5	0.759	0.206	0.191	0.204
6	0.747	0.260	0.545	0.523
7	0.783	0.069	0.242	0.164
8	0.773	0.020*	0.434	0.124

Table A4. Kruskal-Wallis test on learning motivation in PjBL courses

No.	Std.D	Kruskal-Wallis test (*p*-value)		
		Gender	Level	Discipline
1	0.773	0.943	0.183	0.655
2	0.744	0.574	0.267	0.523
3	0.764	0.871	0.361	0.807
4	0.807	0.114	0.857	0.739
5	0.796	0.406	0.268	0.234

Table A5. Kruskal-Wallis test on awareness and knowledge of SDGs

No.	Std.D	Kruskal-Wallis test (*p*-value)		
		Gender	Level	Discipline
1	1.089	0.304	0.525	0.029*
2	1.128	0.362	0.934	0.016*
3	1.058	0.631	0.802	0.007**
4	0.899	0.364	0.798	0.193
5	1.042	0.750	0.860	0.101
6	1.130	0.386	0.503	0.083
7	1.008	0.371	0.275	0.098
8	0.994	0.994	0.694	0.010*
9	0.943	0.751	0.774	0.005**
10	1.038	0.553	0.780	0.036*
11	1.048	0.496	0.748	0.006**
12	1.002	0.552	0.819	0.000**
13	1.053	0.368	0.081	0.095
14	1.088	0.322	0.251	0.013*
15	1.116	0.710	0.643	0.014*
16	1.087	0.738	0.456	0.000**
17	1.032	0.623	0.493	0.146

Table A6. Kruskal-Wallis test on engagement in SDGs

No.	Std.D	Kruskal-Wallis test (*p*-value)		
		Gender	Level	Discipline
1	1.088	0.075	0.403	0.050*
2	1.141	0.206	0.247	0.013*
3	1.048	0.698	0.610	0.018*
4	1.072	0.787	0.572	0.056
5	1.129	0.491	0.571	0.214
6	1.083	0.503	0.225	0.306
7	1.085	0.585	0.026*	0.002**
8	1.032	0.654	0.068	0.011*
9	1.074	0.697	0.611	0.087
10	1.096	0.423	0.088	0.029*
11	1.116	0.616	0.138	0.005**
12	1.093	0.966	0.075	0.012*
13	1.116	0.479	0.215	0.064
14	1.096	0.362	0.287	0.037*
15	1.134	0.825	0.434	0.018*
16	1.089	0.861	0.157	0.006**
17	1.098	0.432	0.037*	0.018*

Table A7. Kruskal-Wallis test on evaluation of SDGs

No.	Std.D	Kruskal-Wallis test (*p*-value)		
		Gender	Level	Discipline
1	0.801	0.002**	0.630	0.018*
2	0.857	0.033*	0.862	0.009**
3	0.761	0.594	0.309	0.635
4	0.773	0.772	0.760	0.184
5	0.755	0.089	0.530	0.105
6	0.786	0.805	0.625	0.509
7	0.794	0.694	0.551	0.216
8	0.824	0.300	0.325	0.031
9	0.783	0.545	0.398	0.436
10	0.833	0.411	0.683	0.085
11	0.806	0.886	0.853	0.083
12	0.795	0.222	0.168	0.156
13	0.784	0.241	0.797	0.034*
14	0.748	0.498	0.501	0.114
15	0.806	0.594	0.837	0.397
16	0.799	0.510	0.166	0.020*
17	0.883	0.827	0.597	0.066

Table A8. ANOVA analysis

		Sum of Squares	df	Mean Square	*F*	*Sig.*
	Between Groups	4.329	5	0.802	2.466	0.034*
SE	Within Groups	60.479	186	0.325		
	Total	64.489	191			
	Between Groups	1.241	5	0.248	0.597	0.702
LM	Within Groups	77.377	186	0.416		
	Total	78.618	191			
	Between Groups	16.945	5	3.389	4.464	0.001*
EN	Within Groups	141.294	186	0.759		
	Total	158.150	191			
	Between Groups	4.807	5	0.961	2.521	0.031*
EV	Within Groups	70.923	186	0.381		
	Total	75.730	191			

Table A9. Descriptive analysis of differences between student groups

Academic disciplines	SE (M ± SD)	AK (M ± SD)	EN (M ± SD)	EV (M ± SD)
Information and Communication Technology	3.637 ± 0.629	3.123 ± 0.935	2.984 ± 1.159	2.960 ± 0.758
Electrical and Electronics Engineering	4.008 ± 0.520	3.926 ± 0.855	3.741 ± 0.825	3.330 ± 0.565
Mechanical Engineering	4.000 ± 0.582	3.966 ± 0.711	3.966 ± 0.745	3.496 ± 0.466
Economics and Management	3.960 ± 0.540	3.704 ± 0.565	3.703 ± 0.789	3.344 ± 0.550
Chemical and Life Sciences	4.042 ± 0.408	3.903 ± 0.540	3.784 ± 0.723	3.278 ± 0.675
Educational Sciences and Technology	3.718 ± 0.791	3.360 ± 1.072	3.665 ± 0.865	3.183 ± 0.706