ISSN: 3116-3475
International Journal
of Education, Research, and Innovation Perspectives
Volume 2 Issue 7 (July 2026)

Student Perceptions on the Effectiveness of Microcontroller and Microprocessor-Based Projects in Achieving SDG-Oriented Learning Outcomes: A TPACK-Guided Quantitative Analysis

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Date Submitted:
March 23, 2026

Date Accepted:
May 18, 2026

Date Published:
July 28 2026

DOI:
10.5281/zenodo.21637891

ABSTRACT

Microcontroller and microprocessor-based projects are increasingly adopted in engineering and technology education for further innovation, problem-solving, and sustainability outcomes. Despite increasing interest in this area, there is limited evidence regarding the contribution of microcontroller and microprocessor-based projects to Sustainable Development Goals (SDGs) when implemented within structured pedagogical frameworks. This study examined student perceptions of projects aligned with SDG 4 (Quality Education), SDG 9 (Industry, Innovation, and Infrastructure), and SDG 17 (Partnerships for the Goals), utilizing the Technological Pedagogical Content Knowledge (TPACK) model as a guiding framework. The study adopted a descriptive quantitative research design involving 43 third-year and fourth-year undergraduate computer engineering students who completed the microcontroller and microprocessor-based projects with sustainability. The data were collected through a 50-item validated TPACK-SDG questionnaire and analyzed using descriptive and inferential statistical methods. The results found a strong positive response with an overall TPACK integration rating of 87.8% (Strongly Agree). The highest scores were obtained in Pedagogical Content Knowledge (PCK, 4.40) and Technological Pedagogical Knowledge (TPK, 4.40) which indicates the effectiveness of project-based, interactive and socially relevant instruction. In contrast, Technological Content Knowledge (TCK, 3.93) received the lowest rating, indicating that support to apply microcontroller and microprocessor technology to specific sustainability outcomes such as renewable energy, health, and environmental systems needs to be increased. These results suggest that the application of microcontroller and microprocessor projects based on SDGs and TPACK can be a model that can be replicated in technical courses to promote the integration of sustainability, innovation, and partnership in higher education curricula.

Keywords: *Microcontroller And Microprocessor-Based Projects; Pedagogical Integration; Sustainable Development Goals; Technological Pedagogical Content Knowledge; Undergraduate Engineering Education*

INTRODUCTION

Rapid technological change has reshaped education, requiring teaching and learning to move beyond traditional boundaries to cultivate globally competent, innovative, and sustainability-driven learners. The microcontroller and microprocessor-based projects, such as those utilizing Arduino and Raspberry Pi technologies, have become valuable tools for promoting hands-on and problem-oriented learning experiences that simulate authentic engineering and sustainability challenges aligned with the United Nations Sustainable Development Goals (SDGs) (Savelidi et al., 2022). Despite this trend, the student perspective regarding the effectiveness of microcontroller and microprocessor-based learning in achieving SDG-oriented learning outcomes remains limited (Dat et al., 2024). Existing research focused on technical skill acquisition, project design, and hardware performance with limited attention to the development of wider competencies such as sustainability awareness, innovation, and social responsibility (Garcia-Tudela & Marin-Marin, 2023; AlAli et al., 2023). This gap is critical since achieving the SDGs requires learners to develop not only technological knowledge but also an understanding of its social, environmental, and ethical implications (Sari et al., 2022).

In the Philippines, educational reforms like Education 4.0 and Outcome-Based Education aim to prepare graduates who are innovative, socially responsible, and aligned with sustainability goals (Widyakusuma & Hakim, 2024; Guerra & Rodriguez-Mesa, 2021). However, many technology and engineering programs still face challenges to effectively embed sustainability and interdisciplinary perspectives into practical, technology-based instruction. While microcontroller and microprocessor-based projects enhance creativity and technical skills, their role in promoting SDG-oriented learning outcomes remains underexplored. This highlights the need to design these projects and implemented to achieve deeper educational objectives (Kioupi & Voulvoulis, 2020).

To address this challenge, the present study employs the Technological Pedagogical and Content Knowledge (TPACK) framework to examine students' perceptions of microcontroller and microprocessor-based projects' effectiveness in achieving SDG-oriented learning outcomes (Rahman & Mehnaz, 2024). The TPACK framework provides a comprehensive understanding of how technology, pedagogy, and content knowledge interact to create meaningful and contextually relevant learning experiences (Diamah et al., 2022). By grounding the study in this model, the research seeks to uncover how the thoughtful integration of microcontroller and microprocessor technologies can enhance both technical proficiency and sustainability-oriented thinking among learners.

Building on this theoretical foundation, the integration of microcontroller and microprocessor-based projects within the TPACK framework aligns closely with constructivist and experiential learning theories, which emphasize learning through active participation, collaboration, and real-world application (Pérez-Rodríguez et al., 2022). The microcontroller and microprocessor-based projects serve as powerful tools for advancing creativity, critical thinking, and problem-solving skills, by engaging with projects linked to the Sustainable Development Goals (SDGs) and simultaneously advancing students' awareness of sustainability and innovation (Polly & Byker, 2020).

Specifically, the study aims to assess students' perceptions of microcontroller and microprocessor-based projects achieving SDG-oriented learning outcomes. Examines the interrelationships of the technological, pedagogical, and content domains of the TPACK framework, and determines collective impact on the development of sustainability-driven engineering competencies. Beyond student perceptions, the research highlights implications for instructional design, curriculum development, and policy in engineering education. By integrating principles of sustainable engineering, innovation, and systems thinking, the research shows how projects can build both technical skills and socio-environmental responsibility. Finally, this study aims to contribute evidence that TPACK-guided, SDG-aligned microcontroller and microprocessor-based projects can serve as transformative tools for the integration of sustainability, innovation, and global citizenship in higher education.

METHODS

Research Design

This study employed a quantitative descriptive–correlational design to evaluate how microcontroller and microprocessor projects support SDG-oriented learning outcomes within the TPACK framework. The design was appropriate for measuring relationships among TPACK constructs and SDG-related learning outcomes without

ISSN: 3116-3475
International Journal
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manipulation of variables. The independent variables were the seven TPACK domains (Enriquez et al., 2021), while the dependent variables were the perceived SDG-oriented learning outcomes aligned with SDG 4 (Quality Education), SDG 9 (Industry, Innovation, and Infrastructure), and SDG 17 (Partnerships for the Goals) (Visioli & Stapleton, 2024).

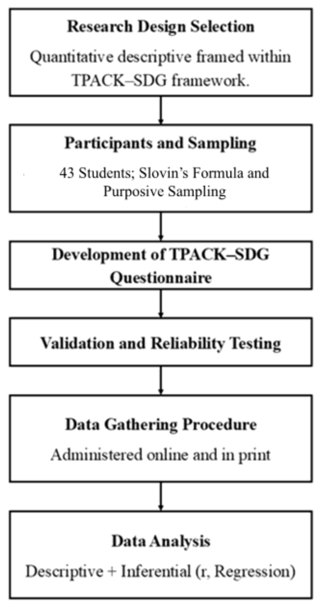

Figure 1. *Flowchart of the Research Methodology*

Research Instrument

The primary research instrument was a 50-item TPACK–SDG Questionnaire, developed by the researcher and subjected to expert validation. The instrument consisted of four sections: (1) demographic profile, (2) TPACK constructs, (3) SDG-oriented learning outcomes, and (4) overall project effectiveness. Each item utilized a five-point Likert scale.

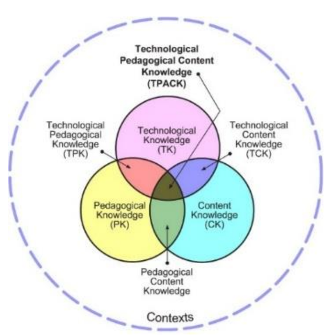

Figure 2. *Technological Pedagogical Content Knowledge Model*

Figure 2 illustrates that the TPACK model integrates three core domains of knowledge: Technological Knowledge (TK), Pedagogical Knowledge (PK), and Content Knowledge (CK). Each domain overlaps to form specialized intersections such as Pedagogical Content Knowledge (PCK), Technological Content Knowledge (TCK), and Technological Pedagogical Knowledge (TPK), which highlight the interdependent nature of teaching, content, and technology. At the core is TPACK, representing the integrated knowledge needed to connect technology with pedagogy and subject matter. The outer circle labeled "Contexts" emphasizes that effective use of TPACK depends on situational and environmental factors influencing teaching and learning practices.

Table 1 *Linguistic Expression of Likert's scale*

Numerical	Range	Verbal Interpretation
5	4.21 – 5.00	Strongly Agree
4	3.41 – 4.20	Agree
3	2.61 – 3.40	Neutral
2	1.81 – 2.60	Disagree
1	1.00 – 1.80	Strongly Disagree

A five-point Likert scale ranging from Strongly Disagree (1) to Strongly Agree (5), as shown in Table 1, was used to measure participants' attitudes and perceptions (Marzuki et al., 2024). The scale assessed seven TPACK domains, technological, pedagogical, content, and their combinations, while examining SDG-oriented outcomes, including cognitive understanding (SDG 4), innovation and problem-solving (SDG 9), and teamwork and collaboration (SDG 17).

To establish content validity, the questionnaire was reviewed by three subject matter experts in engineering education and sustainability pedagogy, resulting in a Content Validity Index (CVI) of 0.91 (Masfuah et al., 2024). Internal consistency reliability was verified using Cronbach's alpha (α), computed as:

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$$\alpha = \frac{k}{k-1}\left(1 - \frac{\Sigma\sigma_i^2}{\sigma_t^2}\right) \qquad \text{Equation 1}$$

In Equation 1, shown as k= number of items, σ_i^2= variance of each item, and σ_t^2= total variance of the summed scale. The computed reliability coefficients ranged from 0.82 to 0.95, indicating high internal consistency.

Sampling Technique

Data collection was conducted during the final week of the semester with third and fourth-year computer engineering students at National University–Baliwag Campus. Questionnaires were distributed both in print and via Google Forms, with sessions lasting about fifteen minutes. Responses were checked, encoded, cleaned, and securely stored in line with data protection policies. A pilot test ensured clarity, reliability, and validity, leading to revisions that improved accuracy. The validated TPACK-SDG questionnaire served as the main tool, and all data were systematically organized and analyzed using appropriate software. Descriptive statistics (mean and standard

ISSN: 3116-3475
International Journal
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deviation) summarized responses, while inferential analyses tested relationships between TPACK constructs and SDG-oriented learning outcomes, ensuring meaningful insights within the framework.

The study examines how TPACK components relate to SDG-oriented outcomes by analyzing correlation strength and predictive influence. Correlations are classified from very weak (0.00–0.19) to very strong (0.80–1.00), with moderate to strong values (0.40–0.79) indicating meaningful connections. Using these benchmarks, the study evaluates how TPACK domains interact to support sustainable education. Multiple regression analysis further identifies the predictive impact of TPACK components on SDG outcomes, with all tests assessed at a 0.05 significance level.

RESULTS AND DISCUSSION

The results of the study revealed that students held a highly positive perception of the effectiveness of microcontroller and microprocessor-based projects aligned with the Sustainable Development Goals (SDGs) under the guidance of the Technological Pedagogical and Content Knowledge (TPACK) framework. The overall mean score across all TPACK domains was 4.24 (SD = 0.88), corresponding to Strongly Agree, indicating that students believed the integration of technology, pedagogy, and content enhanced their learning and supported SDG-oriented outcomes.

Students rated Pedagogical Content Knowledge (PCK) and Technological Pedagogical Knowledge (TPK) the highest (mean = 4.40, Strongly Agree), showing that teaching approaches and technology-supported methods were highly effective for collaboration, creativity, and engagement. Content Knowledge (CK) and Pedagogical Knowledge (PK) also scored strongly (means = 4.22 and 4.25), reflecting deeper understanding of SDG concepts and stronger connections between lessons and real-world sustainability challenges, supported by project-based learning that boosted motivation, teamwork, and critical thinking. Technological Knowledge (TK) and Technological Content Knowledge (TCK) received slightly lower scores (means = 4.11 and 3.93), suggesting confidence in basic microcontroller tasks but less certainty in designing complex systems like renewable energy or IoT-based applications.

Finally, the TPACK (Full Integration) domain scored 4.39 (Strongly Agree), showing that students valued the integration of technology, pedagogy, and SDG-related content, perceiving it as meaningful learning that strengthened technical skills, social awareness, and global citizenship while positioning technology as a tool for social good.

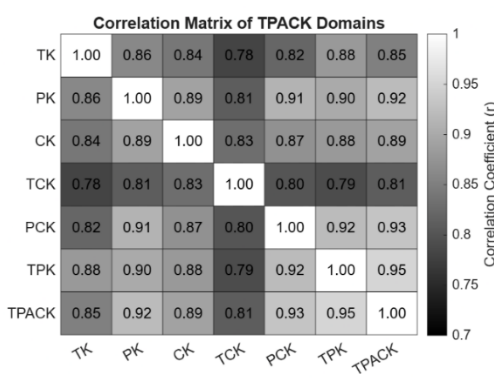

Figure 3. *Correlation Matrix of TPACK Domains*

The correlation matrix, as shown in Figure 3, showed strong positive links across all seven TPACK domains (r = 0.78–0.95), confirming that students' technological, pedagogical, and content knowledge are closely interconnected. The strongest correlations were between Technological Pedagogical Knowledge (TPK) and overall TPACK (r = 0.95), and between Pedagogical Content Knowledge (PCK) and TPACK (r = 0.93), highlighting that effective integration of technology and pedagogy strongly supports SDG-oriented learning outcomes. Pedagogical Knowledge (PK) also correlated highly with Content Knowledge (CK) and PCK, underscoring the importance of instructional strategies in linking theory to practice. Although Technological Content Knowledge (TCK) had slightly lower correlations (r = 0.78–0.83), it still showed positive connections, with advanced applications like IoT and renewable systems posing greater challenges. Overall, the findings affirm TPACK as an interdependent model, where each domain reinforces the others, and microcontroller-based projects enrich both technical skills and pedagogical value for sustainability-focused education.

CONCLUSION

The correlation analysis revealed strong positive links across all TPACK domains, showing that technology, pedagogy, and content work together to achieve SDG-oriented learning outcomes through microcontroller and microprocessor projects. Hands-on, technology-enhanced learning deepened both theoretical and practical understanding, with higher levels of Technological and Pedagogical Knowledge reinforcing overall integration. Meaningful learning arises when instructional strategies, technological tools, and content knowledge align, fostering engagement, creativity, critical thinking, global awareness, and ethical responsibility. Embedding SDG content in technical education prepares students to be innovative and socially responsible professionals, while enhancing Technological Content Knowledge through exposure to advanced fields like IoT, AI, and data analytics, which was recommended to address complex sustainability challenges.

References

AlAli, R., Alsoud, K., & Athamneh, F. (2023). Towards a sustainable future: Evaluating the ability of STEM-based teaching in achieving sustainable development goals in learning. Sustainability, 15(16), 12542. https://doi.org/10.3390/su151612542

Asenahabi, B. M., & Ikoha, P. A. (2023). Scientific research sample size determination. International Journal of Science and Technology. https://doi.org/10.24940/theijst/2023/v11/i7/ST2307-008

Dat, N. D., Bien, N. V., Khuyen, N. T. T., Ha, N. T. V., An, H. T. T., & Anh, N. T. P. (2024). Arduino-based experiments: Leveraging engineering design and scientific inquiry in STEM lessons. International Journal of STEM Education for Sustainability, 4(1), 38–53. https://doi.org/10.53889/ijses.v4i1.317

Dee-Chan, R. (2020). Introducing the technological pedagogical content knowledge (TPACK) framework to the University of Santo Tomas Faculty of Medicine and Surgery. Journal of Medicine, University of Santo Tomas, 4(1), 474–476. https://doi.org/10.35460/2546-1621.2019-0054

Diamah, A., et al. (2022). Evaluating the effectiveness of technological pedagogical content knowledge-based training program in enhancing pre-service teachers' perceptions of technological pedagogical content knowledge. Frontiers in Education, 7, 897447. https://doi.org/10.3389/feduc.2022.897447

Enriquez, M. L., et al. (2021). TPACK: Technology, pedagogy, and content knowledge for paraeducator in the context of Sustainable Development Goal 4. IEEE 13th International Conference on Humanoid, Nanotechnology, Information Technology, Communication and Control, Environment, and Management (HNICEM) (pp. 1–6). IEEE. https://doi.org/10.1109/HNICEM54116.2021.9732019

García-Tudela, P. A., & Marín-Marín, J.-A. (2023). Use of Arduino in primary education: A systematic review. Education Sciences, 13(2), 134. https://doi.org/10.3390/educsci13020134

Guerra, A., & Rodriguez-Mesa, F. (2021). Educating engineers 2030 – PBL, social progress and sustainability. European Journal of Engineering Education, 46(1), 1–3. https://doi.org/10.1080/03043797.2020.1828678

Kioupi, V., & Voulvoulis, N. (2020). Sustainable development goals (SDGs): Assessing the contribution of higher education programmes. Sustainability, 12(17), 6701. https://doi.org/10.3390/su12176701

Marzuki, H. N., Zahirah, I., Lau, M. N., Kuppusamy, E., Mustapha, N. M. N., & Ashari, A. (2024). Likert scale versus the visual analogue scale in evaluating dentofacial aesthetics: A systematic review. Australasian Orthodontic Journal, 40(1), 158–168. https://doi.org/10.2478/aoj-2024-0010

Masfuah, S., Fakhriyah, F., & Hilyana, F. S. (2024). Digitalization and Sustainability for Development Management: Economic, Social, and Environmental Aspects (p. 030001). AIP Publishing. https://doi.org/10.1063/5.0182970

Pérez-Rodríguez, R., et al. (2022). Integrating challenge-based learning, project-based learning, and computer-aided technologies into industrial engineering teaching: Towards a sustainable development framework. Integration of Education, 26(2), 198–215. https://doi.org/10.15507/1991-9468.107.026.202202.198-215

Polly, D., & Byker, E. (2020). Considering the role of zone of proximal development and constructivism in supporting teachers' TPACK and effective use of technology. Revista de Educación a Distancia, 20(64). https://doi.org/10.6018/red.408661

Rahman, P., & Mehnaz, S. (2024). International Journal for Multidisciplinary Research (IJFMR). SSRN Electronic Journal. https://doi.org/10.2139/ssrn.5054029

Sari, U., Çelik, H., Pektaş, H. M., & Yalçın, S. (2022). Effects of STEM-focused Arduino practical activities on problem-solving and entrepreneurship skills. Australasian Journal of Educational Technology, 135–149. https://doi.org/10.14742/ajet.7293

Savelidi, M., Savelides, S., Georgousis, E., Papadopoulou, G., Fasouraki, R., & Drinia, H. (2022). Microcontroller systems in education for sustainable development service: A qualitative thematic meta-analysis. European Journal of Engineering and Technology Research, 53–60. https://doi.org/10.24018/ejeng.2021.0.CIE.2758

Visioli, A., & Stapleton, L. (2024). Control and automation education and UN SDGs: Alignment of TC 9.4 – Current status and future directions. IFAC-PapersOnLine, 58(3), 171–175. https://doi.org/10.1016/j.ifacol.2024.07.145

Widyakusuma, A., & Hakim, R. R. (2024). Crafting engineers for tomorrow: Aligning education with industry to achieve sustainable development. Interdisciplinary Journal of Humanity Injury, 3(11), 741–754. https://doi.org/10.58631/injurity.v3i11.1308