A pilot TAM-based study on student acceptance of the PIC-to-Arduino transition

Nur Izzati Zainal, Nurul Farhana Jumaat#
Faculty of Educational Sciences and Technology,
Universiti Teknologi Malaysia (UTM), 81310, Johor Bahru, MALAYSIA.
#Corresponding author. E-Mail: nfarhana@utm.my.

ABSTRACT Many higher education institutions have adopted Arduino-based platforms for Embedded Systems (ES) education due to their rapid prototyping capabilities. However, it remains unclear whether this adoption is driven primarily by pedagogical ease or perceived alignment with engineering practice. This study investigates student acceptance of Arduino during a transition from PIC microcontrollers by extending the Technology Acceptance Model (TAM) with Perceived Industry Relevance (PIR). A total of 29 diploma-level engineering students with prior PIC experience participated in a four-hour workshop using the Wokwi simulation environment. Data were analysed using non-parametric methods, and 12 cases were excluded due to Insufficient Effort Responding (IER), resulting in an analytical sample of n = 17. Spearman correlation analysis indicates that Perceived Ease of Use (PEOU) shows the strongest association with Attitude Toward Use (AT). Perceived Usefulness (PU) demonstrates significant positive associations with PEOU, PIR, AT, and Behavioral Intention (BI), while PIR does not show significant associations with AT or BI. These findings suggest that, within this sample, student acceptance of Arduino is more closely associated with PEOU and PU than with PIR. This pilot study contributes to ongoing research on technology acceptance in ES education during transitions from low-level to higher-level development environments. The findings highlight the potential importance of usability factors in shaping student acceptance, while also indicating that PIR may play a more limited role in AT and BI formation at early stages of exposure.

KEYWORDS: Embedded systems education; Technology Acceptance Model; Arduino; microcontroller transition; perceived industry relevance; student acceptance
Received 14 May 2026 **Revised** 13 June 2026 **Accepted** 18 June 2026 **In press** 18 June 2024 **Online** 20 June 2026

Short Communication

INTRODUCTION

Traditional Embedded Systems (ES) education often relies on PIC microcontrollers, which, despite their precision, present steep learning curves due to low-level programming requirements (Samiullah *et al.*, 2023). This complexity frequently leads to student frustration (Logozar *et al.*, 2022). Conversely, high-level platforms like Arduino utilize hardware abstraction and simplified IDEs to facilitate rapid development, shifting the learner's focus from configuration to system design.

While previous studies indicate that Arduino enhances engagement and problem-solving skills (Paucar-Curasma *et al.*, 2024), empirical research into how engineering students with prior low-level programming experience perceive this pedagogical transition is limited. Understanding this shift is critical, as adoption depends on learner acceptance of new programming workflows. This study utilizes an extended Technology Acceptance Model (TAM) to investigate this transition, incorporating Perceived Industry Relevance (PIR) to account for the professional expectations of engineering students.

This pilot study explores student acceptance during the transition from PIC to Arduino through an action research intervention. It seeks to answer: (1) What are the levels of PU, PEOU, PIR, AT, and BI among diploma students? (2) What are the relationships between these constructs in a transitional context? (3) To what extent does PIR influence BI within this framework? These preliminary findings aim to contribute to understanding technology acceptance in ES education, particularly in contexts where learners transition from low-level to higher-level development environments.

BACKGROUND THEORY

Previous Works

For many years, PIC microcontrollers (MCUs) have been used as the MCU for learning embedded systems (ES). The PIC MCU is also used in industry as it offers efficiency and can perform tasks in a controlled manner. It uses a low-level programming language, which includes register manipulation and memory management.

It is identified that the limitation of low-level programming is in terms of understanding it, and it is somehow hard for novices to learn. However, there is another platform that support high-level programming languages for learning ES, called Arduino. Previous research by Zlatanov (2015) highlighted that Arduino provide an environment that can facilitate the shift from low to high level programming through the software called Arduino Integrated Development Environment (IDE). Subsequently, some educators have chosen to change the MCU used to learn ES to the Arduino platform (El-Abd, 2017).

In previous studies, many researchers have reported improved student engagement when learning with Arduino (Paucar-Curasma *et al.*, 2024; Sinap & Demirer, 2022; Soonthara, 2020). However, these findings often address engagement at a general level, leaving underexplored the specific factors that influence students' acceptance of the platform. For instance, Paucar-Curasma *et al.* (2024) and Sinap & Demirer (2022) reported higher participation and engagement but do not explicitly examine how students perceive the usefulness, ease of use, or industry relevance of Arduino. This study therefore focuses on technology acceptance factors underlying the transition from PIC MCUs to Arduino, particularly from the perspective of students with prior experience in low-level MCU programming. Therefore, to understand the cognitive and procedural shift required of learners, it is necessary to contrast the PIC and Arduino platforms across dimensions relevant to this study. This comparison, summarized in Table 1, highlights the transition from component-level to platform level environment.

Table 1. Comparison between component-level (PIC) and platform-level (Arduino) development environments

Dimension	PIC Microcontroller (Component-Level)	Arduino Platform (Ecosystem-Level)
Programming Style	Low-level C and Assembly; lack of support for simple integrated environments (Rankovska & Goranov, 2020)	Simplified C++ (Wiring) within a pre-configured IDE framework (Zlatanov, 2015)
Hardware Interaction	Direct control through manual register manipulation (Logozar *et al.*, 2022)	Contain pre-written code libraries that reduce the complexities of programming the hardware (El-Abd, 2017).
Peripheral Setup	Manual configuration of internal registers for modules like ADC, I2C, and EUSART (Rankovska & Goranov, 2020)	Standardized libraries for rapid interfacing of GPIO, I2C, and SPI (Zlatanov, 2015)
Application Focus	Optimized for reliability and versatile use in real industrial applications (Rankovska & Goranov, 2020)	Prioritized for educational prototyping and iterative design (El-Abd, 2017)

From Table 1, the main differences between PIC and Arduino are in terms of ease of programming and hardware setup. To develop ES using PIC, usually students need to manage the hardware setup. However, PIC programming requires the students to implement register-level manipulation.

Rankovska & Goranov (2020) highlight that this approach involves professional in-circuit debugging and compilers, which are different from the Arduino IDE that has a simpler environment. The need for detailed knowledge of MCU architecture often arises from low-level hardware configuration requirements, which can demand considerable effort and may divert attention from primary problem-solving tasks (El-Abd, 2017; Pasricha, 2022).

Meanwhile, the Arduino platform uses a simpler language (high-level) that is easier to learn and faster for development. One of its advantages is that it has built-in libraries. Because of this, students can focus on system-level integration compared to PIC, where they spend a lot of time dealing with register-level complexity. Zlatanov (2015) and El-Abd (2017) mention that although Arduino appear as an alternative for learning ES, the idea is not about complexity, but rather that this shift can help students reduce the heavy effort required for configuring the MCU.

In addition, the shift from PIC to Arduino is also driven by the growth of the community using Arduino. Although the PIC MCU is reliable in industrial applications, its complex configuration can create a barrier for students learning the platform. Therefore, changing to Arduino platform provides learners with an environment that is easier to program and manage in terms of hardware. Consequently, this choice effectively lowers the barrier for beginners and supports the rapid development cycles required in modern ES education.

Conceptual Framework

The Technology Acceptance Model (TAM) was first introduced by Davis (1989), proposing two primary determinants of technology acceptance: Perceived Usefulness (PU) and Perceived Ease of Use (PEOU). PU refers to the extent to which an individual believes that using a technology enhances their performance, while PEOU refers to the degree to which a technology is perceived as easy to use.

This study extends TAM by introducing Perceived Industry Relevance (PIR), which refers to students' perception of how closely learning and using a technology aligns with contemporary engineering tools, workflows, and practices commonly applied in professional industrial context. In embedded systems education, students may evaluate a platform not only based on its usefulness and ease of use, but also on whether it reflects technologies and workflows commonly used in professional engineering environments. Therefore, PIR captures the perceived relevance of Arduino to contemporary engineering practice.

While PIR shares conceptual similarities with the notion of job relevance reported in technology acceptance research, particularly within the Unified Theory of Acceptance and Use of Technology (UTAUT) framework proposed by Venkatesh *et al.* (2003), the constructs differ in scope, target population, and context. Job relevance generally refers to the extent to which technology is perceived as applicable to tasks required in an individual's current job role within an organizational setting (Venkatesh & Davis, 2000; Venkatesh *et al.*, 2003). Consequently, it assumes that users have direct workplace experience from which they can evaluate the technology's contribution to job performance. In contrast, PIR is designed for pre-employment engineering students who have limited direct exposure to industrial practice. Rather than evaluating a technology based on current job-task requirements, students assess whether a learning platform reflects technologies, tools, and workflows commonly associated with contemporary engineering environments. PIR therefore captures the perceived educational-to-industry alignment of technology, namely the extent to which students believe that learning and using Arduino is relevant to modern engineering practice. This distinction is important because established technology acceptance frameworks, including UTAUT, were originally developed for workplace technology adoption contexts (Venkatesh *et al.*, 2003), whereas the present study examines technology acceptance within an educational environment where industry exposure is indirect rather than experiential. In this study, PIR is also examined as a potential outcome of PU while simultaneously being tested as a predictor of Attitude Toward Use (AT) and Behavioural Intention (BI) within the extended TAM structure.

Therefore, PIR is introduced as a context-specific extension of TAM to capture students' perceptions of educational-to-industry alignment during the transition from PIC microcontrollers to Arduino-based learning environments. Thus, this study proposes the conceptual framework illustrated in Figure 1, which is designed for technical learning environments where students evaluate new tools based on prior exposure to lower-level microcontroller programming. The model incorporates students' perceptions of usability, usefulness, and industry relevance during this transition.

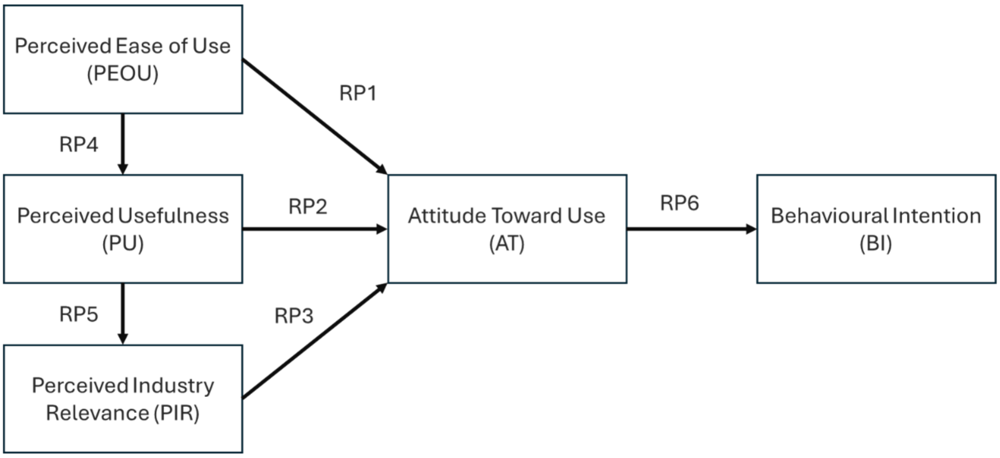

Figure 1. Conceptual framework for investigating student acceptance of Arduino platforms in embedded systems (ES) education based on the Technology Acceptance Model (TAM)

The proposed conceptual model (Figure 1) integrates six research propositions (RP) connecting traditional TAM constructs with the newly introduced PIR variable. Determinants of AT are addressed in RP1 (PEOU→AT), RP2 (PU→AT), and RP3 (PIR→AT). Additionally, the model hypothesizes inter-belief relationships where ease of use influences utility (RP4: PEOU→PU), and perceived utility informs professional value (RP5: PU→PIR). Finally, RP6 (AT→BI) examines the link between student AT and the BI to adopt Arduino in future engineering projects.

METHODOLOGY

Research Design

This pilot study employed an action research design as introduced by Kemmis *et al.* (2014), involving cycles of planning, action, observation, and reflection to evaluate the transition from PIC microcontrollers (MCUs) to Arduino. The participants consisted of 29 diploma engineering students (18 males and 11 females) from a Malaysian polytechnic, selected through purposive sampling based on their prior experience with PIC MCUs.

Student acceptance was measured using an 18-item questionnaire adapted from the Technology Acceptance Model (TAM). The instrument included five constructs: Perceived Usefulness (PU), Perceived Ease of Use (PEOU), Perceived Industry Relevance (PIR), Attitude Toward Use (AT), and Behavioural Intention (BI). All items were measured using a five-point Likert scale. The PIR construct was introduced to capture students' perceptions of the extent to which Arduino aligns with current engineering practice and industry expectations. The complete measurement instrument is presented in Table 2.

Table 2. Measurement items for the extended Technology Acceptance Model (TAM)

Code Construct	Measurement Statement
PU1	Using Arduino improves my learning performance.
PU2	Using Arduino increases my productivity in embedded systems learning.
PU3	Using Arduino makes my learning process easier.
PU4	I find Arduino useful for my learning in embedded systems.
PEOU5	Learning to use Arduino is easy for me.
PEOU6	My interaction with Arduino is clear and straightforward.
PEOU7	I can learn new Arduino features quickly.
PEOU8	The features of the Arduino IDE are easy to navigate.
PEOU9	Basic Arduino tasks such as selecting the board and port and uploading a sketch are easy.
PIR10	Skills with Arduino are valued in real industry projects.
PIR11	Understanding Arduino is relevant to industry roles.
PIR12	Arduino knowledge is relevant to current engineering industry needs.
AT13	Using Arduino for learning is a good idea.
AT14	Using Arduino is enjoyable.
AT15	I like using Arduino for learning embedded systems.
BI16	I intend to continue using Arduino in my learning.
BI17	I will frequently use Arduino in coursework or projects.
BI18	I plan to explore more advanced Arduino applications.

Observation of participant fatigue led to the identification of 12 straight-lined responses categorized as Insufficient Effort Responding (IER). To maintain data quality, these responses were excluded from the correlation analysis ($n = 17$) but retained in the descriptive analysis ($N = 29$) for cohort transparency.

RESULTS AND DISCUSSION

Preliminary Analysis

Preliminary analysis (Table 3) shows that the full sample (N=29) shown significant ceiling effects and non-normality ($p < .001$). Removal of invariant responses (n=17) adjusted the mean scores to a more realistic range (4.05 – 4.20) and improved normality for PU, PEOU, and PIR ($p > .05$).

Table 3. Descriptive statistics and normality tests for full and analytical samples

Construct	Full Sample (N=29)			Analytical Sample (n=17)				
	Mean	SD	p-value	Mean	SD	Min	Max	p-value
PU	4.52	0.64	<.001	4.18	0.65	3	5	0.144
PEOU	4.44	0.63	<.001	4.05	0.55	3	5	0.601
PIR	4.47	0.64	<.001	4.10	0.6	3	5	0.354
AT	4.53	0.6	<.001	4.20	0.59	3	5	0.028
BI	4.48	0.56	<.001	4.12	0.46	3	4.67	0.011

Correlation Analysis

Spearman's rho (r_s) was calculated to examine relationships within the extended TAM (Table 4), and effect sizes (r^2) were reported as variance explained. Correlation strength was interpreted primarily using benchmarks for individual differences research (Gignac & Szodorai, 2016), where values of approximately 0.10, 0.30, and 0.50 indicate small, moderate, and strong relationships, respectively. These thresholds are consistent with Cohen's (1988) general guidelines for effect size interpretation.

Table 4. Spearman's rank correlation matrix (n=17)

Relationship	Spearman's rho, r_s	p-value	Effect size, r^2
Mean_PU - Mean_PEOU	0.682**	0.003	0.465
Mean_PU - Mean_PIR	0.800***	<.001	0.640
Mean_PU - Mean_AT	0.698**	0.002	0.487
Mean_PU - Mean_BI	0.569*	0.017	0.324
Mean_PEOU - Mean_PIR	0.366	0.149	0.134
Mean_PEOU - Mean_AT	0.822***	< .001	0.676
Mean_PEOU - Mean_BI	0.675**	0.003	0.456
Mean_PIR - Mean_AT	0.341	0.181	0.116
Mean_PIR - Mean_BI	0.339	0.183	0.115
Mean_AT - Mean_BI	0.644**	0.005	0.415

The strongest correlation was observed between PEOU and AT (r_s = 0.822, $p < .001$, r^2 = .676), suggesting that ease of use is the strongest associated factor with student attitude. PU also demonstrated strong significant relationships with PIR (r_s = 0.800), AT (r_s = 0.698), and PEOU (r_s = 0.682), while maintaining a moderate path to BI (r_s = 0.569). Notably, PIR did not significantly correlate with PEOU, AT, or BI ($p > .05$). This indicates that while students recognize the platform's usefulness, its perceived industry relevance is not a dominant factor in forming attitudes or intentions in this sample. Finally, AT significantly predicted BI (r_s = 0.644, p = 0.005), confirming that when students have a positive experience with Arduino, they are much more likely to choose it for their future work.

Discussion

These preliminary empirical findings (Table 5) provide partial support for the extended Technology Acceptance Model (TAM) in the context of transitioning from PIC microcontrollers to Arduino-based learning. Overall, the results suggest that student acceptance of Arduino in this sample is primarily associated with perceived ease of use and perceived usefulness.

Table 5. Summary of research proposition outcomes (n=17)

Proposition	Relationship Path	Spearman's rho (r_s)	p-value	Effect size, r^2	Result
RP1	PEOU→ AT	0.822	< .001	0.676	Supported
RP2	PU→AT	0.698	0.002	0.487	Supported
RP3	PIR→AT	0.341	0.181	0.116	Not Supported
RP4	PU→ PIR	0.800	< .001	0.640	Supported
RP5	PEOU→ PU	0.682	0.003	0.465	Supported
RP6	AT→ BI	0.644	0.005	0.415	Supported

The strongest relationship identified is between Perceived Ease of Use (PEOU) and Attitude Toward Use (AT) (PEOU→AT, RP1), suggesting that students' perceptions of how easy Arduino is to use play a central role in shaping their attitudes toward the platform. Arduino's simplified development environment and structured programming interface may contribute to this perception. This is further supported by the significant relationship between PEOU and Perceived Usefulness

(PU) (PEOU→PU, RP5), indicating that students who perceive Arduino as easier to use are also more likely to perceive it as useful for learning embedded systems.

PU also shows a significant positive relationship with Attitude Toward Use (AT) (PU→AT, RP2), confirming that students' beliefs about the educational value of Arduino contribute to their overall attitude toward the platform. Additionally, the significant PU to Perceived Industry Relevance (PIR) relationship (RP4) suggests that students who perceive Arduino as useful are also more likely to associate it with relevance to engineering practice and industry contexts. However, PIR did not show a significant relationship with AT (PIR→AT, RP3). This indicates that while students may recognize Arduino's relevance to industry, this perception does not strongly influence their immediate attitude formation in this sample. Instead, usability and usefulness are more influential in shaping acceptance.

The significant AT to Behavioural Intention (BI) relationship (AT→BI, RP6) confirms that positive attitudes toward Arduino are associated with students' intention to continue using the platform in future coursework and projects. Overall, the results suggest that acceptance of Arduino in this sample is primarily associated with PEOU and PU, while PIR is closely associated with PU but does not show significant relationships with AT or BI in this sample. These findings indicate that usability-related factors may play a more prominent role in technology acceptance within embedded systems learning environments.

CONCLUSION

This study examined student acceptance of Arduino during a transition from PIC microcontrollers using an extended Technology Acceptance Model (TAM) incorporating Perceived Industry Relevance (PIR). The study was conducted as a pilot investigation with diploma-level engineering students who had prior experience with PIC-based embedded systems. The results suggest that Perceived Ease of Use (PEOU) and Perceived Usefulness (PU) are the primary factors associated with students' attitudes toward Arduino. In particular, PEOU shows the strongest association with Attitude Toward Use (AT), indicating that usability plays an important role in shaping initial acceptance within this sample. PU is also positively associated with AT and with PIR, suggesting that perceived usefulness may contribute to students' recognition of industry relevance.

In contrast, PIR does not show a significant association with AT or Behavioural Intention (BI) in this study. This indicates that, at this stage of exposure, perceived alignment with industry practice may not be a primary driver of students' intention to use Arduino, compared to usability-related factors. The findings should be interpreted with caution due to the small analytical sample size ($n = 17$), the single-institution context, and the reliance on self-reported measures. As such, the results are best understood as exploratory.

Future research is recommended to replicate this study with larger and more diverse samples, and to further examine the role of PIR in different stages of learning and exposure to embedded systems platforms. Longitudinal designs and more advanced modelling approaches (e.g., regression or structural equation modelling) may also provide deeper insight into the relationships proposed in the extended TAM framework.

ACKNOWLEDGEMENTS

This research was fully funded by Universiti Teknologi Malaysia (UTM), (Vot. No. Q.J130000.3853.23H80). The authors would like to express their sincere gratitude to UTM for providing financial support to carry out this study.

REFERENCES

[1] Cohen, J. 1988. *Statistical Power Analysis for the Behavioral Sciences* (2nd edition). Hillsdale, New Jersey: Lawrence Erlbaum Associates.

[2] Davis, F. D. 1989. Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology. *MIS Quarterly*, 13(3), 319–340.

[3] El-Abd, M. 2017. A Review of Embedded Systems Education in the Arduino Age: Lessons Learned and Future Directions. *International Journal of Engineering Pedagogy (IJEP)*, 7(2), 79 - 93.

[4] Gignac, G. E. & Szodorai, E. T. (2016). Effect size guidelines for individual differences researchers. *Personality and Individual Differences*, 102, 74–78.

[5] Kemmis, S., McTaggart, R. & Nixon, R. 2014. *The Action Research Planner - Doing Critical Participatory Action Research*. Singapore: Springer Singapore.

[6] Logozar, R., Horvatic, M., Sumiga, I. & Mikac, M. 2022. Challenges in Teaching Assembly Language Programming – Desired Prerequisites vs. Students' Initial Knowledge. *Proceedings of the 2022 IEEE Global Engineering Education Conference (EDUCON)*. 28-31 March 2022, Tunis, Tunisia. pp. 1689–1698. (https://doi.org/10.1109/EDUCON52537.2022.9766737). Last accessed on 13 May 2026.

[7] Pasricha, S. 2022. Embedded Systems Education in the 2020s: Challenges, Reflections, and Future Directions. *Proceedings of the Great Lakes Symposium on VLSI 2022*. June 6–8, 2022, Irvine, CA, USA. pp 519–524.

[8] Paucar-Curasma, R., Unsihuay Tovar, R. F., Villavicencio Jiménez, S. C. A., Jara Jara, N., Gonzales Agama, S. H. & Quijada-Villegas, J. H. 2024. Developing IoT Activities Using the Problem-Solving Method: Proposal for Novice Engineering Students. *Mathematical Modelling of Engineering Problems*, 11(11), 3161-3172.

[9] Rankovska, V. V. & Goranov, G. D. 2020. PIC Microcontroller Module in a Flexible Microprocessor Development System. *Proceedings of the 2020 55th International Scientific Conference on Information, Communication and Energy Systems and Technologies (ICEST)*. 10-12 September 2020, Nis, Serbia. pp. 3–6.

[10] Samiullah, M., Irfan, M. Z. & Rafique, A. 2023. Microcontrollers: A Comprehensive Overview and Comparative Analysis of Diverse Types. *TechRxiv preprint*. (https://doi.org/10.31224/3228). Last accessed on 13 May 2026.

[11] Sinap, V. & Demirer, V. 2022. Use of Arduino activities through problem-based learning in programming education: An action research. *Eğitim Teknolojisi Kuram ve Uygulama*, 12(2), 351–376. (https://doi.org/10.17943/etku.1035265). Last accessed on 13 May 2026.

[12] Soonthara, S. 2020. The development of online lessons to enhance practical skills with problem-based learning on microcontroller Arduino for undergraduate students. *Interdisciplinary Research Review*, 15(3), 20–24.

[13] Venkatesh, V. & Davis, F. D. 2000. A theoretical extension of the technology acceptance model: Four longitudinal field studies. *Management Science*, *46*(2), 186–204.

[14] Venkatesh, V., Morris, M. G., Davis, G. B. & Davis, F. D. 2003. User acceptance of information technology: Toward a unified view. *MIS Quarterly, 27*(3), 425–478.

[15] Zlatanov, N. 2015. Arduino and open source computer hardware and software. *ResearchGate preprint*. (https://doi.org/10.13140/RG.2.1.1071.7849). Last accessed on 13 May 2026.