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ORIGINAL RESEARCH

Significance of Teaching of Microcomputer Technology through Practical Robotic Ground Vehicle Application

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Abstract
Teaching the technology behind microcomputers to beginner students can be challenging due to the fundamental knowledge they need to grasp. Students must understand what happens in the "brain" of microcomputers to comprehend the complexities of the technology. This paper outlines a pragmatic approach that includes a practical implementation of problem-solving techniques for a microcomputer course, focusing on a robotic ground locomotive vehicle as the application. This involved assembling and seamlessly integrating mechanical, electrical, and microcontroller elements, using two software programs: Flowcode and Proteus. Evaluation of the implementation's efficacy includes quantitative and qualitative measures. Results were evaluated based on achievements throughout the course, and students' feedback was gathered through a questionnaire at the end of the course. Various aspects were assessed through the questionnaire, including the effect of the practice on students' understanding, the alignment with the curriculum, and how the practice boosted students' interest in the field. The analysis showed that the approach had a very positive impact on students, with an average score of 4.16 for application relevance and 4.29 for overall student involvement, based on a Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). Most students recommended continuing the exercise, with the most common rating being 5 (strongly agree). The findings underscore the value of hands-on, application-oriented pedagogies in facilitating effective learning experiences within microcomputer education.

Keywords Microcomputer Course · Microcontroller Course · Practice-Oriented · Hands-On

Introduction

Teaching of the technology behind microcomputers to a group of beginner students can be a challenging task, particularly when the students lack a solid foundation in information and communication technology. Merely elucidating various levels of computer languages and the explanation of diverse number systems within the framework of microcomputers falls short in adequately equipping them, especially with the aim of producing capable engineers of the future with sufficient capability for system integration.

In the past, microcomputer technology instruction, encompassing microprocessors and microcontrollers, typically relied on conventional classroom lectures. These lectures primarily focused on delving into the architectural and programming facets of microcomputers, with minimal attention given to practical hardware interfaces. A survey in [1] for a 20-year-period trend of microcomputer education affirms the matter. Ref [2]. provides several drawbacks of the method such as inability of student to comprehend the content of course, loss of interest and ineffective assessment.

Nonetheless, numerous efforts have been made to address this issue by adopting various approaches. Several authors pointed out the significance of integrating project-based learning into student's curriculum, including for institutions of higher education [3–6]. Whilst some look at the challenges for the university, other researchers reported the outcome achieved by the students [7–10]. Some researchers

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have successfully embedded the idea of project-based learning to certain education courses and abled to increase quality of teaching and student satisfaction [11–13].

On a more focused study for microcomputer-related courses, ref [14]. detailed three distinct methods employed by educators: (1) simulation-based instruction, (2) computer unit operation-based instruction, and (3) the utilization of commercial training kits. They argued that there is a strong opinion favouring the effectiveness of the latter approach over the former two. Such an approach may be traced e.g. in [15] that emphasized the teaching of microcomputer course for solving practical monitoring and control problems. They shared on how this may be benefitted with a step-by-step guidance to the students. Ref [1]. presented that there is 411% change in the use of teaching tools in microcomputer education. More educators use software and hardware in their teaching.

Among those who has made the change is in [16] that also highlighted the advantages of incorporating practical sessions within a microcomputer course. The author showcased how it was used to instruct students on various microcomputer applications such as temperature monitoring, pressure monitoring, and electronic piano operation, which hold relevance for a wide range of engineering students. Ref [17]. similarly described an instructional approach centred on a practical demonstration involving data transfer and digital display. They concluded that the approach increase students' interest and improve the effectiveness of teaching in comparison to traditional blackboard teaching. Ref [18]. describes an act of the same approach, namely using embedded system, within the context of problem-based learning. Ref [19]. listed out various other strategies related to hands-on practice and concluded with excellent responses from the student in their application.

Furthermore, even for students in the electronics major, the implementation of teaching microcomputer technology through projects is seconded as in [20]. Several different projects were taught to counter the necessary specializations. Students who learned through practical applications developed their practical ability effectively and teachers were easily able to cultivate innovation and cooperation [21]. On the teaching of Internet of Things using microcomputer, ref [22]. noted the integration of practical experience for students through student-oriented competition strategy. However, the students had been prepared with other microcomputer-related topics through other courses.

Different practical applications may be more suitable for different groups of non-electronic and non-computer-related major students for them to appreciate the microcomputer technology. This is so that they are able to relate such isolated course easily to their selected study major. As learning microcomputers require interdisciplinary knowledge and an understanding of abstract concepts, mechanical engineering students tend to find the application of microcomputers in mechanical instruments particularly engaging.

The study presented in this paper puts a specific focus on teaching microcomputer technology to beginner mechanical engineering students through a practical, project-based approach involving a robotic ground vehicle. The study distinguishes itself from other studies as the curriculum is tailored for mechanical engineering students. It documents the delivery of a microcomputer technology course, specifically "Microprocessor Technology," to second-year students within the Faculty of Mechanical Engineering at Universiti Teknikal Malaysia Melaka.

This paper describes the process of devising an appropriate curriculum, which seamlessly melds the theoretical underpinnings with hands-on application of microcomputer technology. The curriculum needed to be designed to fit within the confines of a single semester, spanning approximately 14 weeks of study, and meeting the requirements of a 2-credit graduation prerequisite. The 2-credit course counts roughly to a 2-hour meeting weekly aside from other classroom hour engagement. Unlike other studies that rely solely on qualitative feedback, this research includes both quantitative measures from a detailed questionnaire survey and practical performance evaluations of the robotic vehicle.

The paper is organized as follows: Sect. 2 explains how the curriculum was divided into theoretical and practical portions, followed by an explanation of how the practical exercise was achieved. After the practical exercise, a questionnaire survey was handed out to the students and Sect. 3 presents the findings. Section 4 concludes the study.

Methodology

Considerable deliberation was invested in ensuring that students received a sufficient understanding of microcomputer architecture and the intricacies of internal bit communication, all while emphasizing practical application. The semester was structured into two segments, with the initial portion dedicated to imparting the core principles of microcomputers, encompassing a brief historical overview, architectural insights, and teaching of arithmetic and logic operations, as detailed in Table 1. This portion was aimed primarily to introduce and provide some early insights to the course that contained some rare terminologies (to them). At this stage, the students gathered some useful visualizations as to how computer components communicate and how some basic calculations are done within a computer through its gates and buses.

The second portion was dedicated to equipping them for a practical assignment, specifically focusing on the

Table 1 Microprocessor technology course content

Semester	Content
First portion	•History and components of microcomputer •Microcomputer architecture •Arithmetic and logic operation •Computer number system •Microcontroller characteristics
Second portion	•Flowcode programming •Proteus simulation •Embedded application on robotic vehicle •Assignment Troubleshooting

development of an application involving a robotic ground vehicle. This second portion included teaching, with real demonstration of, computer programming using Flowcode software and simulation of source code execution using Proteus software.

To be methodically specific, the application employed a single PIC16F84 chip, a versatile 8-bit microcontroller featuring 18 pins. This microcontroller utilizes FLASH/EEPROM technology and boasts compatibility with a wide array of programming software [23]. The characteristics such as its architecture and computer blocks were taught in the first portion of the semester. Without delving too deep, the communication protocols were also taught.

Two softwares were introduced and these were Flowcode and Proteus also known as Proteus Design Suite. Flowcode is a user-friendly programming software that employs a graphical programming style similar to flow charts for code development. Students were not required to acquire proficiency in conventional programming languages like C in order to create their codes. The software is designed to be accessible to individuals without programming experience and also offers straightforward simulation capabilities to validate code accuracy.

Following this, the codes were then saved and sent to Proteus software where the students learned on electronic design and assembly. After assembly of the electronic components, the codes may be tried as embedded instructions in a PIC16F84 simulated microcontroller to execute needed jobs. As a start, the jobs of LED lighting, LCD information display, motor rotation etc. may be verified through simulation. Throughout this second portion, since the assignment was distributed to groups of 5–6 students each, guidance and suggestions were provided weekly or on query basis to assist them in completing the task, mainly to coach them through the process.

The task involved constructing a robotic vehicle utilizing a hobbyist car chassis, such as the one available for purchase online from GI Electronic, identified as the 2WD Smart Robot Car Chassis with the code R0100006 [24]. Additionally, students were tasked with programming a PIC16F84 microcontroller so that the vehicle is able to navigate through five ground checkpoints within a confined ground area measuring approximately 2 m by 2 m (Fig. 1). In the exercise, different groups were given different routes.

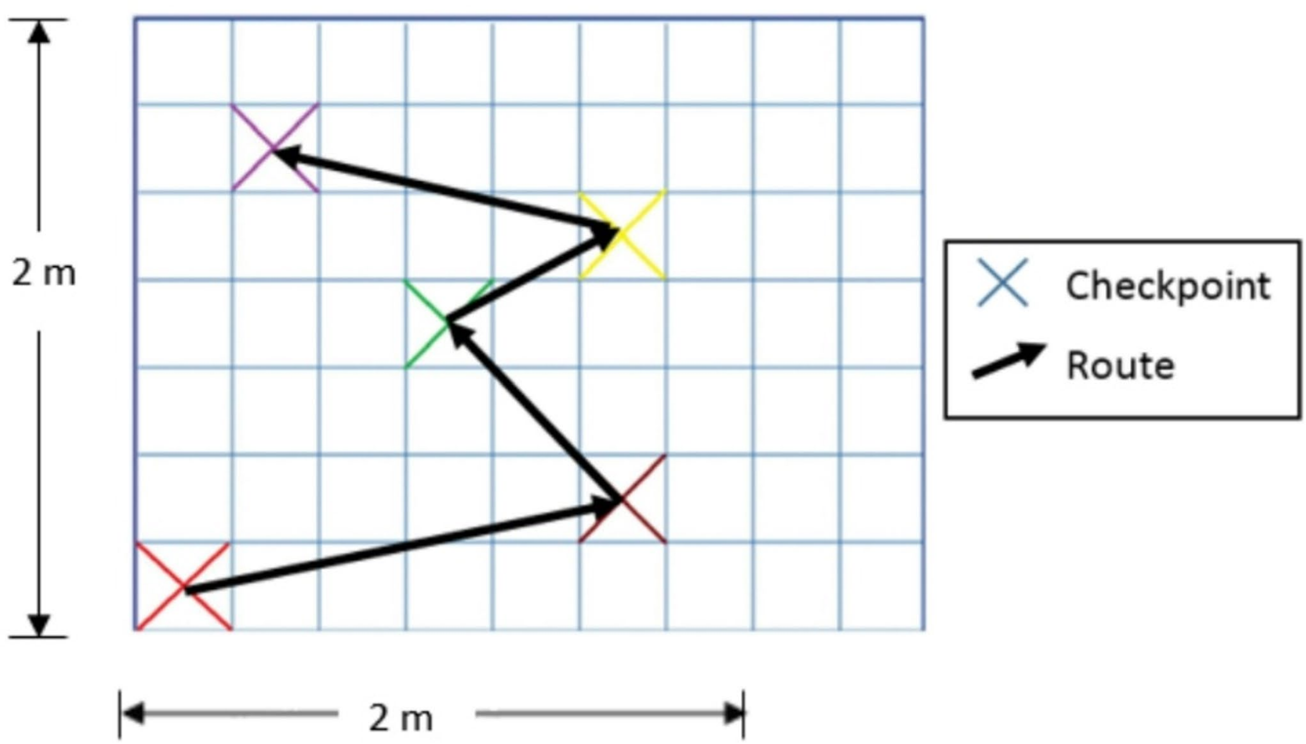

Fig. 1 Example of an overhead view of route map for robotic vehicle traversing multiple checkpoints

Following the completion of the source code, instructors facilitated the process of importing the file into the PIC hardware connected to all other components, in particular, 2 DC motors, within the car chassis.

Figure 2 illustrates the flow chart of the practical exercise conducted in the "Microprocessor Technology" course. It begins with planning of the exercise execution followed by code programming, where students design and write the necessary codes using the Flowcode software to control the vehicle's movements. Collaboratively, some group members move on to circuit development, assembling the electronic components and ensuring proper connections. The next step involves circuit simulation, where students validate their code within a simulated environment in Proteus software to verify functionality before actual implementation. The process concludes with prototype development and testing, where evaluation is made on the vehicle's performance against the defined checkpoints. The structure highlights the educational value within each step of project-based learning in microcomputer technology.

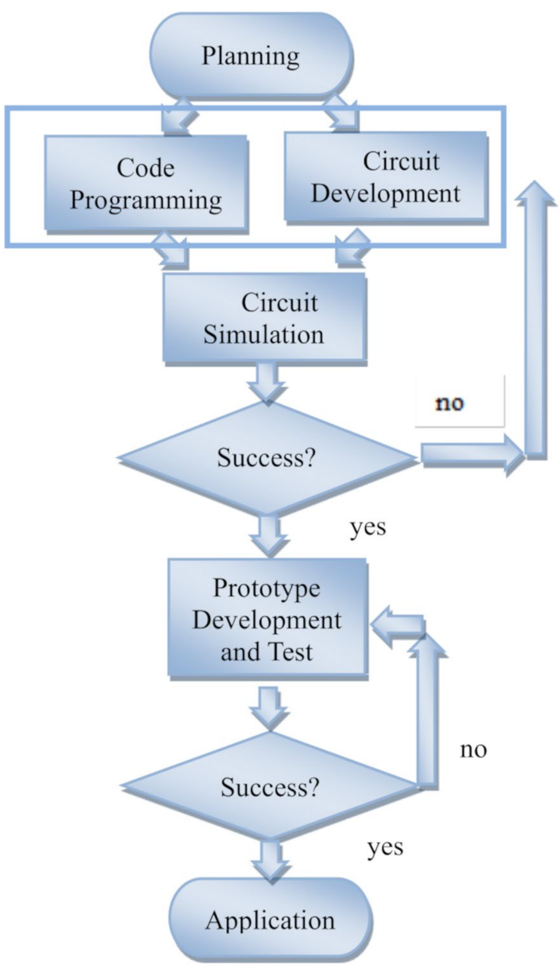

Fig. 2 Flow chart of course practical exercise

Results and Discussion

The results and discussion of the exercise in this paper are divided into two sections. The first one is on the practical achievement of the students while the second one delves into their perceptions regarding the exercise through a questionnaire.

Practical Achievement

During the evaluation session, the vehicle underwent testing on several criteria, which encompassed the count of checkpoints successfully traversed, the time it took to complete the task, and the measurement of the distance error between the vehicle's last stop and the last checkpoint. Figure 3 shows the assembled vehicle created by one of the student groups, while Fig. 4 captures an image of a vehicle on the day of evaluation. It is worth noting that the students exhibited considerable enthusiasm from the start of the project through to the evaluation day. At the conclusion of the assessment, an overall score of 5.9 out of 8 was achieved, encompassing an average rating of 4 out of 5 checkpoints reached. This score signifies the student's proficient mastery of Flowcode blocks, control of straight and turning movements with precise timing (demonstrating a deep grasp of microcontroller processing frequency and wheel synchronization), and a strong understanding of bit transfer communication, as exemplified in the Proteus simulation.

The project-based learning method significantly bolstered students' comprehension and empowered them to delve into and address challenges beyond initial expectations. These included:

- • Strategies for overcoming obstacles on the ground surface.
- • Strategies for overcoming electrical deficiencies in system.
- • The efficient assembly and seamless integration of mechanical and electrical components.
- • The precise execution of turns and the approximation of time measurement for travel.

It can be noted that the project also enhanced their abilities in communication, interaction, and teamwork. Students constantly share their experience about the execution of their project (Fig. 5).

Questionnaire Analysis

Following the practical exercise, an anonymous questionnaire was handed out to all 230 students of the course, and received a response rate of 100% as participation was

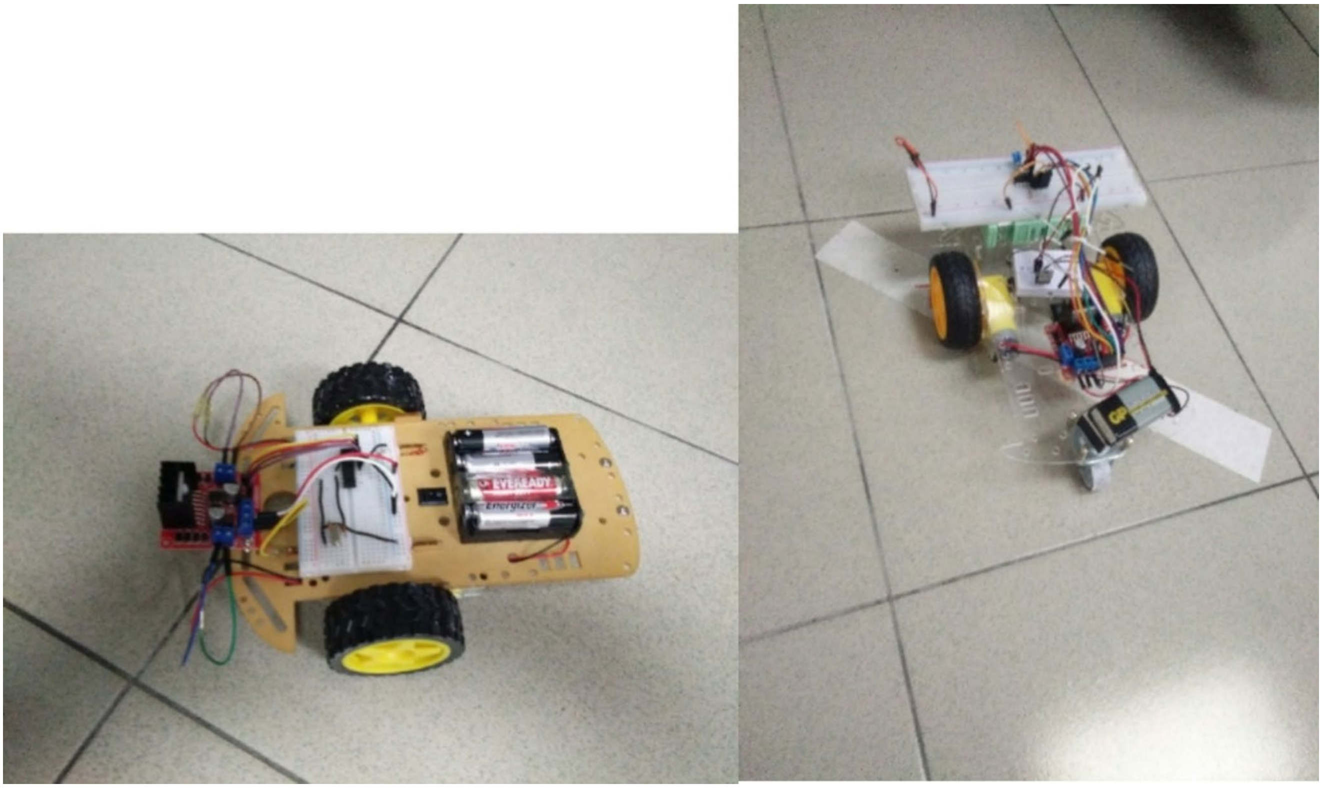

Fig. 3 Robotic ground vehicles built by microcomputer course student groups

Fig. 4 Robotic ground vehicle during evaluation

Fig. 5 Students sharing experience on conduct of project

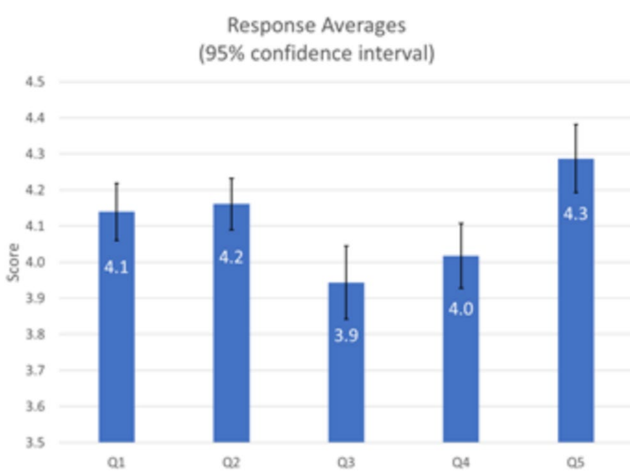

Fig. 6 Overall Response on Questionnaire Analysis

conducted during course evaluation. The questionnaire consisted of 5 questions as follows and given a 5-point Likert scale options beginning from "Strongly Disagree" as the first option, with a score of 1 to "Strongly Agree", with a score of 5:

Q1: The given project increased my understanding of the given theory. (Effectiveness)

Table 2 Statistics of questionnaire response

	Q1	Q2	Q3	Q4	Q5
Mean	4.139	4.161	3.943	4.017	4.287
Standard Error	0.040	0.037	0.052	0.046	0.048
Mode	4	4	4	4	5
Standard Deviation	0.611	0.557	0.783	0.699	0.733
Kurtosis	2.070	2.189	-0.086	1.841	-0.115
Skewness	-0.662	-0.414	-0.452	-0.797	-0.709

Q2: I have applied what I learnt from the theory in my project. (Relevance)

Q3: This project increased my interest in mechanical engineering (specifically microcomputer technology) (Instilling interest).

Q4: This project increased my soft skills (leadership, communication, teamwork etc.) (Soft skill development).

Q5: This exercise should be continued for other future students. (Involvement).

Figure 6 shows the overall responses from the respondents. Question 1 (Q1) evaluated whether the project increased students' understanding of the theoretical concepts, and the positive responses with a score of 4.1 indicated a significant improvement in their grasp of microcomputer technology. Meanwhile, Question 2 (Q2) focused on the relevance of the project, with many students affirming with a score of 4.2 that they could apply the theoretical knowledge gained in their projects to real-world scenarios. Question 3 (Q3) assessed the project's effect on students' interest in mechanical engineering and microcomputer technology. Although this question received the lowest average score of 3.9, it still indicated a generally favourable shift in interest levels. The responses for question 4 (Q4) on the development of soft skills demonstrated with a score of 4.0 that the students felt that the project contributed positively to their interpersonal skills. Moreover, based on question 5 (Q5), when asked whether the exercise should be continued, a strong agreement, with the highest score of 4.3, emphasized the positive value that the students place on the project-based approach.

Table 2 provides other important descriptive statistics of the questionnaire responses. From The table, the mode for Q5 (Involvement) is 5 whilst the others are 4. The highest skewness is from Q4 (Soft skill development) while the lowest is from Q2 (Relevance). The data distributions for each question are provided in the collection of histograms in Fig. 7. The data together with Table 2 reflects a predominantly positive perception among students regarding the practical exercise. For instance, the average scores across the five questions reveal strong agreement, with the highest mean of 4.29 for involvement (Q5), indicating that most students believed the exercise should continue for future cohorts. The histograms show a left-skewed distribution for questions related to the effectiveness and relevance of

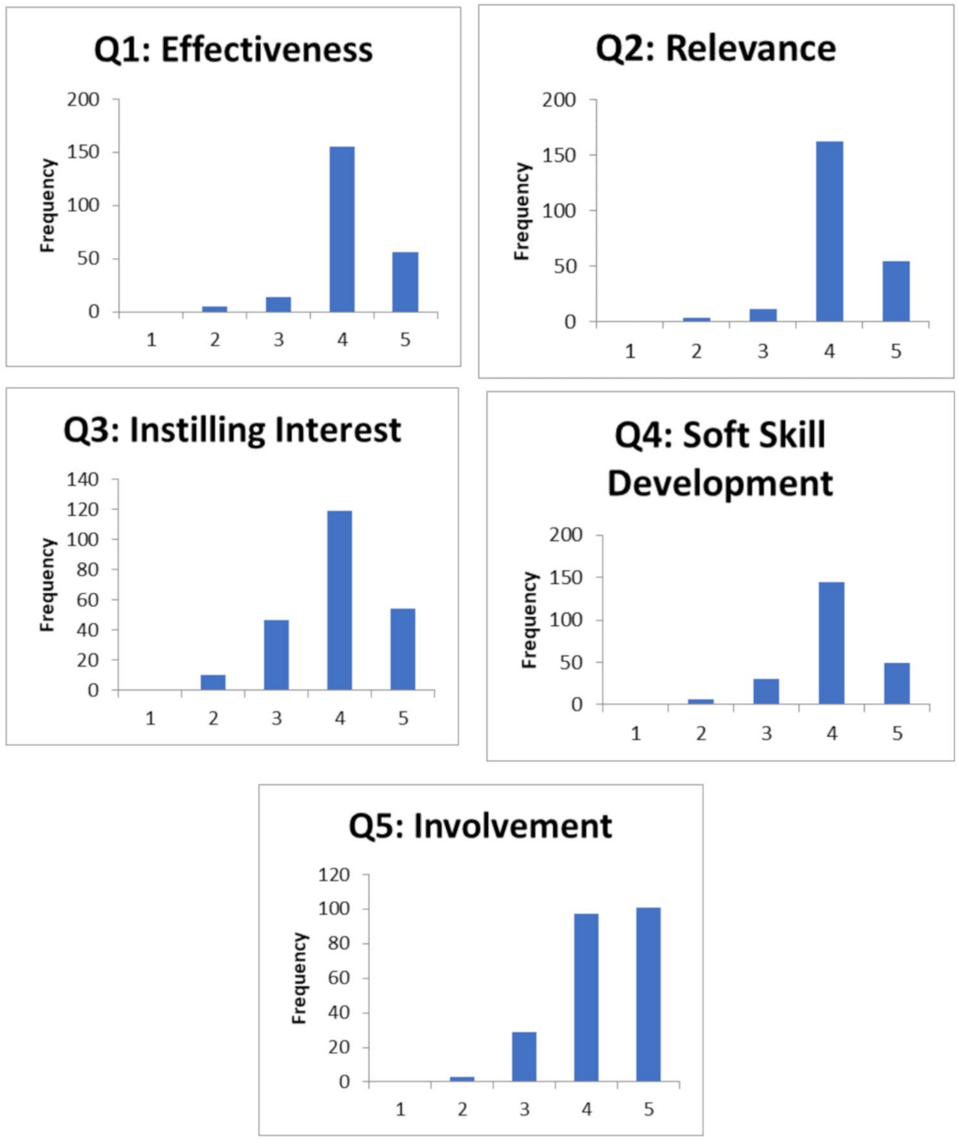

Fig. 7 Histogram of Responses for Different Questionnaire Component

the project, with means of 4.14 (Q1) and 4.16 (Q2), respectively. This suggests that students felt the project significantly enhanced their understanding of theoretical concepts and was highly applicable to their coursework.

In contrast, Question 3 (Q3), which measured interest had a mean score of 3.94. The histogram for this question indicates some variation in responses, suggesting that while many students experienced an increase in interest, there were those who remained neutral or less enthusiastic. For soft skills development (Q4), even though the mean score is 4.02 indicating a positive perception, the histogram reveals that some students felt the impact on their interpersonal skills was not as pronounced. The data shows that even though many students agree that the exercise is relevant to the content of the course, some do not quite feel that it develops soft skill as much as it is relevant. This is further supported by the skewness values; the highest skewness was found in Q4 at -0.8, indicating a broader range of opinions among students. Nonetheless, based on the kurtosis value, the numbers of the outliers are considered small. For all the questions, the highest absolute kurtosis is 2.189 which may be considered a light tail for a distribution, while the centres are around the "Agree" position.

Conclusion

The teaching of a microcomputer course through practical assignments to a group of students of early mechanical engineering background is hereby reported. In this study, the teaching of microcomputer technology through practical application enabled the students to clearly grasp and appreciate the capability of microcomputer technology towards bridging the gap between abstract concepts and real-world implementation. The quantitative and qualitative data collected from the questionnaire highlighted that students generally agreed that the project significantly improved their understanding of microcomputer principles, with a high mean score of 4.14 for understanding, and 4.16 for relevance. While the project succeeded in increasing interest for many students (mean score of 3.94), the variability in responses for this aspect indicates that further refinements may be necessary. Similarly, the development of soft skills, such as teamwork and leadership, was positively perceived (mean score of 4.02), although this area could also benefit from additional focus. More advanced tasks — such as multi-sensor integration or decision-making algorithms — can be incorporated in future iterations to provide deeper problem-solving opportunities for more advanced learners.

The project's overall success, evidenced by the strong recommendation to continue this practical approach (mean score of 4.29), underscores the emphasis of application to real mechanical instrument yet prepares them better for formal exam-based assessment where knowledge of code and circuit development are further tested. Future iterations of this course could explore a broader range of applications to further enhance engagement and accommodate diverse learning styles, possibly integrating interdisciplinary projects that connect mechanical, electrical, and computer engineering. Additionally, future work may benefit from implementing longitudinal tracking or comparative study designs to better assess long-term knowledge retention and skill transfer beyond the duration of the course. Overall, this study highlights the importance of practical, project-based learning in microcomputer education and provides a framework for future educational strategies in similar technical fields.

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Data Availability The datasets generated and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Research Involving Human And/or Animals This study does not involve experiments on animals or the collection of personal data from human participants.

Informed Consent Informed consent was not required as the study did not involve identifiable human data.

Competing Interest The authors have no competing interests to declare that are relevant to the content of this article.

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