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Development and evaluation of an instructional trainer for microcontroller programming

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Abstract
In the context of Industry 4.0, vocational education must prepare students for industries transformed by digital technologies. This study evaluates a microcontroller programming training kit aimed at enhancing practical competencies in line with Industry 4.0 requirements. Using a developmental-mixed method design guided by the ADDIE model and a sequential explanatory approach, the study involved needs analysis, design, development, implementation, and evaluation phases. The research was conducted at Bukidnon State University and involved 20 full-time lecturers from two state universities. Two survey instruments assessed the design, technical aspects, and usefulness of the training kit and instructional materials, using a five-point Likert scale to quantify responses.
The results indicate highly positive feedback across all evaluated aspects. The design received high ratings for feasibility, ergonomic layout, and clarity, supporting effective learning processes. Technical aspects such as reliability, ease of use, maintenance, and safety were also highly rated. The training kit was deemed an effective teaching aid, significantly enhancing student understanding and engagement. Qualitative feedback suggested design refinements, safety improvements, and innovative features such as the integration of the LoRa 32 OLED and additional cameras for monitoring student performance.
The study concludes that the microcontroller programming training kit is highly effective and well-received, significantly improving the teaching and learning experience in microcontroller programming. The findings underscore the importance of well-designed instructional tools in vocational education, highlighting their role in fostering student engagement and practical skills development. The research provides a foundation for further improvements and future studies on the long-term impact of such educational tools.

Keywords: Microcontroller programming, training kit evaluation, industry 4.0, ADDIE model

Introduction

In the context of Industry 4.0, vocational education teachers must prepare students to enter an industry transformed by digital technologies. Industry 4.0, characterized by interconnected technologies and digital transformation, enhances real-time communication and process control in manufacturing and service firms. The Philippines recognizes innovation as crucial for economic growth and is committed to the UN's Sustainable Development Goals (SDGs), specifically targeting resilient infrastructure and sustainable industrialization (SDG 9).
Microcontroller programming is vital for Industry 4.0, integrating advanced digital technologies into smart industrial systems. This skill empowers students to innovate and enhance industrial processes through hands-on practice, bridging the gap between theoretical knowledge and practical application.
Higher Education Institutions (HEIs) are essential in developing competencies for Industry 4.0, using creative and flexible learning strategies. Despite efforts to use diverse teaching methods, the lack of essential hardware and practical training resources hampers students' ability to apply theoretical knowledge effectively.
Addressing these resource constraints through better resource allocation and support is necessary to enhance the effectiveness of instructional approaches and improve students' learning outcomes in microcontroller programming. The development of instructional trainers and learning guides tailored to specific hardware components can significantly improve students' competencies and bridge the gap between academia and industry needs.

Materials and Methods

This study employed a developmental-mixed method design, guided by the ADDIE model (Analysis, Design, Development, Implementation, and Evaluation) and a sequential explanatory mixed method approach. The research began with a needs analysis to identify gaps between the current state and the desired outcomes, utilizing literature reviews and other resources. The design phase focused on content strategy for the Microcontroller Programming Training Kit. The development phase involved creating a prototype evaluated by experts, followed by the implementation phase where the kit was tested in real-world scenarios. The final evaluation phase assessed the kit's effectiveness and gathered suggestions for improvement.
The study was conducted at Bukidnon State University, Malaybalay City, with evaluations at both Bukidnon State University and the University of Science and Technology of Southern Philippines. Data analysis, interpretation, and presentation were carried out at Bukidnon State University. The sampling involved twenty experts from the two universities, selected through purposive sampling. These experts were full-time lecturers with at least two years of experience to ensure they had sufficient teaching experience to provide valuable insights.
A survey questionnaire was used assess the design, technical aspects, usefulness of the training kit and the qualitative feedback of the perceived by the experts. The instrument measured various indicators, such as interface design, component layout, reliability, ease of use, and the ability to facilitate learning. A five-point Likert scale was employed

to quantify responses, providing a detailed understanding of the participants' views. The experts simply checked the numbers with their corresponding description on the questionnaire. The choices given were: 5-Strongly Agree; 4-Agree; 3- Neither agree or disagree; 2- Disagree; and 1-Strongly Disagree as shown in Table A.

Table A: Likert Scale

Likert Scale	Qualitative Description	Interpretation
5	Strongly agree	Respondents believe the trainer/learning guide is highly effective and perfectly meet their needs.
4	Agree	Respondents find the trainer/learning guide is effective with minor reservations or possible improvements.
3	Neither agree or disagree	Respondents are indifferent or find the trainer/learning guide only moderately effective.
2	Disagree	Respondents feel the trainer/learning guide is lacking in effectiveness.
1	Strongly disagree	Respondents believe the trainer/learning guide do not meet their learning needs at all.

Results and Discussion

The data collected from the evaluations of the instructional trainer and the learning module are analyzed to identify strengths and areas for improvement. The discussion interprets these results in the context of the objectives of the study.

Problem 1. What is the quality of the developed instructional trainer?

a. Design Aspect

The survey results for the design aspect of the microcontroller programming trainer are highly positive. Respondents strongly agree that the trainer is effective, with mean ratings ranging from 4.65 to 4.9 across various design aspects. The design and feasibility of the trainer, as well as its size, received high ratings of 4.9, indicating it meets the needs of the students effectively. Studies confirm the importance of well-designed trainers in enhancing learning outcomes and student satisfaction.

The organized and neat layout of components scored 4.8, while the clarity of component names and symbols earned ratings of 4.75 and 4.8, respectively. These features make the trainer user-friendly. The clarity and organization of educational tools are critical for effective learning.

The ease of understanding component symbols was rated 4.65, and the appropriateness of cable lengths and component locations received ratings of 4.75 and 4.79, respectively. The selection of color plugs, rated at 4.84, and the ergonomic design, rated at 4.75, further highlight the trainer's practicality and comfort for users. Ergonomic and intuitive designs are shown to improve user interaction and learning efficiency.

Overall, these high ratings suggest that the instructional trainer is well-designed, effective, and supports the learning process in microcontroller programming. These conclusions are supported by research highlighting the benefits of well-structured training kits in technical education.

b. Technical Aspect

The survey results for the technical aspect of the microcontroller programming trainer are highly positive. Respondents strongly agree that the trainer is effective across all evaluated statements as shown in Table B. The trainer was rated as 4.95 for its use by teachers as a learning medium, indicating it meets their needs perfectly. It was rated as 4.90 for making it easier for teachers to explain microcontroller programming concepts, and with a rating of 4.85 for effectively supporting the delivery of learning materials. These high ratings align with research entitled "Performance of Trainers kits for Industrial Automation Based on Programmable Logic Controllers", which indicates that well-designed training tools significantly enhance the teaching process and improve student engagement.

The trainer also received a rating of 4.90 for improving students' understanding of the microcontroller programming course, showing its significant impact on learning. It was rated as 4.75 for helping to shorten the learning time, and with a rating of 4.85 for increasing student attention during lessons. Lastly, it was rated as 4.85 for boosting students' interest in learning microcontroller programming. These findings are supported by studies conducted in Asia, which demonstrate that effective educational tools lead to better learning outcomes and increased student interest.

Overall, its effectiveness in facilitating teaching, enhancing understanding, and increasing student engagement underscores its importance as an educational tool. The trainer's ability to support efficient and effective learning processes is evident from the consistently high ratings, suggesting it significantly enhances the teaching and learning experience in microcontroller programming. This observation is further reinforced by research highlighting the positive impact of microcontroller training kits on students' practical skills and theoretical knowledge.

Problem 2. Experts Feedback on Microcontroller Programming Trainer

The qualitative feedback from the evaluation of the microcontroller programming training kit and learning guide provides insightful suggestions and commendations from respondents. These comments are categorized into several key themes, reflecting areas for improvement and appreciation of the current design and functionality as shown in Table B.

Table B: Thematic Analysis of the Expert's Feedback

Themes	Feedback
Design	▪ Slight refinement on the actual trainer. ▪ Convert the body into plastic to avoid electric shocks from AC wire. ▪ Label for the pin's polarity. ▪ Please consider the longevity of the device, especially the components locking system/mechanism. Properly locked components will help with longevity and maintenance. ▪ Include component support. ▪ You can add a camera to monitor and record the performing student intended for busy instructors.

	▪ Nice presentation of the different components, the integration of the LoRa 32 OLED is a superb idea. ▪ You might incorporate a wireless bullet camera, all in all, 100% approved for this prototype.
Usability	▪ The trainer is handy or portable and indeed suitable for the needs of the students.
Safety	▪ Convert the body into plastic to avoid electric shocks from AC wire.

The following discussion synthesizes the feedback to highlight the primary areas of design, usability, safety, and innovation and integration, which are crucial for enhancing the overall effectiveness and user satisfaction of the training kit.

Design

The feedback on the design of the microcontroller programming trainer emphasizes several key improvements. Respondents suggested refining the trainer's overall functionality, converting the body to plastic for safety, and labeling pin polarity for clarity. Enhancing the component locking system is crucial for durability and maintenance. Including component support and adding a camera to monitor student performance would enhance usability. The integration of the LoRa 32 OLED was praised, and incorporating a wireless bullet camera was recommended. These enhancements aim to improve the trainer's practicality, safety, and effectiveness.

Usability

The trainer was praised for being handy and portable, making it suitable for student needs. This portability is crucial for practical, on-the-go learning environments.

Safety

Safety concerns were noted, with specific recommendations to convert the body into plastic to prevent electric shocks from AC wires. This change would significantly enhance the safety of the trainer for both students and instructors.

Respondents appreciated the integration of different components, especially the LoRa 32 OLED, considering it a superb idea. Suggestions included adding a camera to monitor and record student performance, which would be particularly beneficial for busy instructors. The incorporation of a wireless bullet camera was also proposed, and the prototype received 100% approval for its innovative design and functionality.

These themes and feedback highlight the strengths of the microcontroller programming training kit while providing actionable suggestions for further improvement, particularly in design, usability, safety, and innovative integration.

Conclusion

The microcontroller programming training kit received overwhelmingly positive feedback across all aspects. In terms of design, it was rated highly for feasibility, ergonomic layout, and clarity. Technically, it was commended for reliability, ease of use, maintenance, and safety. In terms of its usefulness, it was deemed an effective teaching aid, enhancing student understanding and engagement. Therefore, the microcontroller programming training kit is highly effective and well-received by both teachers and students, enhancing the learning experience through its thoughtful design, reliable technical performance, and significantly useful educational value.

Respondents provided several suggestions for the microcontroller programming training kit. They recommended design refinements, converting the body to plastic for safety, labeling pin polarity, and enhancing the component locking mechanism for durability. The trainer was praised for its portability, making it suitable for practical learning environments. Safety improvements included converting the body to plastic to prevent electric shocks. Innovation and integration were appreciated, especially the LoRa 32 OLED, with suggestions to add cameras for monitoring student performance. These themes highlight strengths while offering actionable improvement suggestions in design, usability, safety, and innovation.

The results underscore the significant role of the training kit in microcontroller programming education. Its comprehensive design, technical reliability, and practical usefulness make it a valuable educational tool. The high ratings and positive feedback indicate that it effectively supports both teaching and learning processes. The findings highlight the importance of well-designed instructional materials and tools in enhancing educational outcomes and fostering student engagement in technical subjects. This study provides a solid foundation for future improvements and further research into the long-term impact of such training kits on educational practices.

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