Journal of Education, Teaching, and Learning
Volume 9 Number 2 September 2024. Page 89-95
p-ISSN: 2477-5924 e-ISSN: 2477-8478

FEASIBILITY TEST OF A TESTING STATION TRAINER SITUATED IN VIRTUAL REALITY INTEGRATES COMPUTATIONAL THINKING CONCEPTS

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Abstrak. This research focuses on integrating the Computational Thinking (CT) concept of automation system in vocational education to address the high costs and scarcity of educational resources in practical learning. The rapid industrial expansion of automation, particularly in Modular Production Systems (MPS), requires students to grasp both the components' functionalities and operational principles. Another point that needs to be considered is the integrated CT concept in the learning process. The CT skills facilitate students in dealing with problems throughs systematic problem-solving strategies. To reduce cost and address scarcity, this research developed an Interactive Virtual Reality Testing Station (IVRTS) to effectively replicate MPS in a Flexible Manufacturing System (FMS) Laboratory setting. The IVRTS, integrated with a CT approach to provide students with an experimental learning platform to tackle these challenge by implementing four key components: decomposition, pattern recognition, abstraction, and algorithm. The research objective is to investigate the feasibility of the IVRTS for users. The research procedure was adopted from Lee Owens' ADDIE development model to create a CT-based IVRTS as an innovative educational tool. Experimental validation will assess the efficacy of CT-enhanced IVRTS among 36 students from higher schools. Based on the results of research on the IVRTS indicates its significant potential, receiving mainly "Good/Worth It" feedback. Despite the overall positive reception, users reported issues regarding its complex nature and the necessity for ongoing technical support. Refinements to make the system more intuitive and autonomous by streamlining the interface and clarifying functions are essential for broader user adoption.

Keyword : flexible manufacturing system, mps-testing station, interactive virtual reality, computational thinking, systematic problem-solving

I. INTRODUCTION

In the current educational discourse, the acquisition of critical thinking and problem-solving skills is deemed essential for navigating the complexities of the 21st century, as delineated by Wu, W.-R., and Yang, K.-L. (2022). These abilities are integral to the suite of competencies designed to prepare students for the multifaceted challenges presented by ongoing technological and environmental changes. Educational systems are thus urged to embed these capabilities within their curricula to facilitate robust problem-solving strategies among students. Furthermore, the paradigm of problem-solving has undergone significant transformations to better align with contemporary and emergent technological demands, a perspective reinforced by Haataja et al. (2019). In this vein, the conceptual framework of Computational Thinking (CT), as introduced by Wing (2006), represents a fundamental shift towards integrating principles from computer science to enhance the problem-solving capacity of individuals.

The concept of Computational Thinking (CT) is increasingly recognized as an essential element within the educational framework, applicable from early learning stages through various academic levels, as highlighted by Bers and colleagues (2019) alongside Israel-Fishelson and Hershkovitz (2022). The scholarly interest in CT, particularly in the international context, has seen a notable surge, evidenced by a consistent increase in scholarly publications annually, as documented by Ulas et al. (2018) and Tang et al. (2020). Research has unequivocally demonstrated CT's widespread applicability and positive effects across different academic disciplines. For instance, CT has been shown to bolster mathematical reasoning skills (Denning, 2017; Hsu & Hung, 2018; Kynigos & Grizioti, 2018), enhance problem-solving abilities within programming and robotics (Bers et al., 2014; Bermúdez et al., 2019), and improve logical reasoning in the social sciences through narrative-based approaches (Parsazadeh et al., 2021). Given this empirical support, the integration of CT methodologies within the Indonesian educational system, particularly in vocational institutions, becomes a pressing necessity.

On the other hand according by Sudira (2016), 21st century learning is strongly influenced by the development of science, technology, and engineering. The techno-science-socio-cultural approach will lead students to become psychologically, socially, culturally, technologically, and scientifically intelligent,. The application of automation technology in today's industry is massive and growing very fast. Industry requires fast, effective and efficient production. The application of PLC-based automation systems on production machines is inevitable. The industrial revolution 4.0 combines physical systems with non-physical systems or so-called cloud computing so that the production process is controlled by artificial intelligence. The preparation of labor in accordance with the needs and development of industrial technology must be carried out by educational institutions. The success of learning objectives cannot be separated from learning facilities and infrastructure. Practicum teaching aids are tools used in practicum learning so that students have knowledge and skills through direct experience in the laboratory. Vocational education is closely related to mastery of skills. One of the skills acquired is through practical learning. Expensive teaching aids and their limited availability are challenges in practical learning.

Vocational schools in Indonesia are synonymous with preparing graduates with specific skills needed by industry. One example of expertise is programming control components with the aim of imitating a production work system. In this programming, the complexity of problems that arise, making essential to integrate CT as a problem-solving technique which involves four key components: decomposition, pattern recognition, abstraction, and algorithm. In addition, CT in this specific learning provides guidance to students how to complete programming appropriately and efficiently as highlighted by Boom et al. (2022) and Kale & Yuan (2021). However, not all vocational schools in Indonesia have evenly distributed programming equipment. Limited facilities can be a factor that hinders the preparation of students as prospective graduates with specific abilities, such as programming and computational thinking. Therefore, breakthroughs that match technological advances and allow it to be widely applied in vocational schools need to be created.

In educational frameworks, the Modular Production System (MPS) serves as an artificial production system. Understanding the functions and working principles of MPS components is crucial. However, direct observation of these components is limited to external views, with inner constructions often obscured. Datasheets provide only static two-dimensional images and written explanations. To address this limitation, a learning medium capable of displaying three-dimensional digital reconstructions with moving images is necessary to explain MPS component workings effectively. The use of computer-based learning media is rapidly growing in today's digital era, as highlighted by Imam Habibie (2020) on the kemendikbud.go.id website, emphasizing the increasing trend of ICT-based media in learning. Multimedia learning, particularly interactive moving visuals, positively influences student learning outcomes, as evidenced by Negara's findings (2017). Belyaev & Shiyan (2018) support this notion, affirming that interactive learning multimedia, conveyed through computers or smartphones, effectively delivers knowledge and skills to students.

Integrating computational thinking into practical learning of Flexible Manufacturing Systems (FMS) using Modular Production System 500 series (MPS-500) trainers is essential. The MPS-500 prototype production process line, detailed by Herarsi et al. (2021), incorporates a PLC-based automation system, allowing students to manipulate programs according to demand. FMS practice aims for students to identify pneumatic and electro-pneumatic mechanical components, including their names, functions, and working principles. However, direct component identification on the MPS-500 takes time as students shift their focus between physical observation, specification data, and component narratives. To address this, a virtual environment displaying the MPS-500 components' physical form, working principles, and specifications is necessary.

This research spans two years, with the first year dedicated to developing the Interactive Virtual Reality of Testing Station (IVRTS). IVRTS will describe the construction and simulate the working process of electro-pneumatic mechanical components, with a notable feature being Scratch programming with block diagrams, supporting computational thinking learning (Lamb & Johnson, 2011). This integration of computational thinking in IVRTS offers an ideal platform for vocational students to enhance problem-solving skills.

This study aims to investigate the feasibility of technology development concerning the IVRTS from the users' perspective. After the development phase, the next step is to validate the technology based on user feedback and scores. To address the research objectives, this study proposes two research questions:

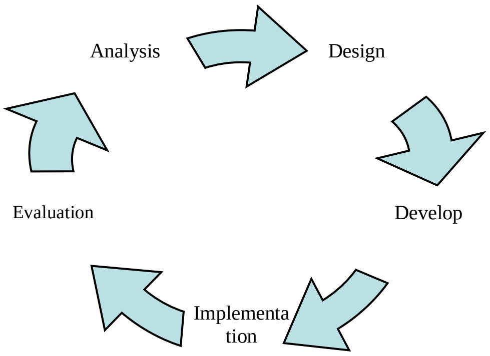
1. How to develop IVRTS?
2. How do users experience the technology developed in IVRTS?

II. METHODS

This research was conducted at the Department of Electrical Engineering Education, Faculty of Engineering, Yogyakarta State University from July 1 2023 to December 31 2023. This research uses theoretical foundations based on relevant theories and concepts to support problem solving in research. Aspects that are used as a theoretical basis to achieve the objectives of this research include: 1) multimedia learning, 2) development of computer-based learning multimedia, 3) unit testing stations on MPS-500, and 4) relevant research.

This part focuses on developing Interactive Virtual Reality Testing Stations (IVRTS) for virtual PLC programming laboratory demonstrations. Adopt a Research and Development (R&D) approach, specifically using the ADDIE development model as our basic framework.

FIGURE 1. ADDIE TECHNOLOGY DEVELOPMENT APPROACH



Analysis Phase:
The initial steps extend beyond surface-level examination, delving deep into identifying the specific needs and requirements through a comprehensive literature review and meticulous observations in existing Flexible Manufacturing System (FMS) laboratory practices. This detailed investigation to uncover the gaps between current educational practices and industry demands. The focus is on a vocation-centric learning approach, where the priority shifts towards providing practical, hands-on experiences over traditional theoretical instruction, ensuring learners acquire relevant, job-ready skills. This transition is supported by integrating advanced multimedia technologies, fostering an environment where learners can engage with and create interactive content. This innovative approach not only enhances learning experiences but also prepares students for the real-world challenges they will face in their vocational careers.

Design Phase:
This phase involves meticulous planning, defining the scope of work, and setting achievable deadlines to ensure project completion within the allocated timeframe. Detailed specifications of product features are crafted, outlining the functionalities and user interface requirements, aligning with the core objectives of the learning platform. The learning structure is configured to cater to diverse educational needs, promoting an effective and interactive learning environment. Plans are regularly revisited and refined based on feedback and evolving project needs. The anticipated outcomes include ensuring the product's compatibility with Windows Operating System, seamless integration with PLC (Programmable Logic Controller) programming devices, and a robust mechanism to accurately display the input/output status directly from the PLC, enhancing the learning experience and facilitating practical understanding of PLC operations.

Development Phase:
In this phase, the focus is on designing an intuitive and user-friendly interface, developing efficient user interaction mechanisms, and constructing a reliable technical architecture. The process involves drafting detailed interface specifications, which guide the design of the interactive elements and ensure a seamless user experience. Additionally, the development includes robust error debugging processes and comprehensive integration testing, employing black-box testing methodologies to ensure that the system functions correctly and efficiently without needing to delve into the internal logic or structure.

FIGURE 2. IVRTS DESIGN

Implementation Phase:

This phase involves conducting a small-scale study where a group of 36 students from the Department of Electrical Engineering Educationis selected to use and explore the newly developed product. Prior to the initiation of data collection, it is imperative to underscore that the instrument has undergone validation by two specialists in instrument design and two experts in content validity, and has accordingly been adjudged appropriate for application. Their interactions and experiences with the product are closely monitored, and comprehensive feedback is collected from a diverse set of stakeholders including domain experts, media specialists, and instructors. This feedback is integral for identifying any shortcomings or areas of improvement, enabling the development team to make necessary adjustments and enhance the product's effectiveness and user-friendliness through iterative improvements.

Evaluation Phase:
Evaluation method entails deploying detailed questionnaires via Google Forms, featuring nuanced Likert scale questions, to precisely evaluate the developed educational media's performance. This structured feedback mechanism enables an in-depth analysis of user responses, which are then systematically assessed using normal distribution intervals to categorically determine the effectiveness and suitability of the media in educational settings. This robust analytical approach allows for a more granular understanding of the media's impact on learning outcomes and user satisfaction.

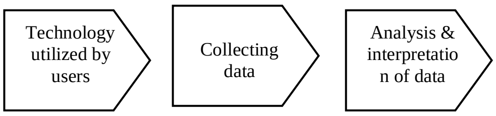


FIGURE 3. TECHNOLOGY VALIDATION PROCESSTABLE 1. LIKERT SCALE QUESTIONNAIRE

No	***Questionnaire of Interactive Virtual Reality Testing Stations (IVRTS) for virtual PLC programming laboratory demonstrations***					
	Statement	**Scale**				
		Strongly Disagree				Strongly Disagree
		1	2	3	4	5
1	**Intention to Use** "I think I will use this Virtual Reality app often."					
2	**Complicated to Use** “Saya merasa aplikasi Virtual Reality ini rumit untuk digunakan.”					
3	**Easy to Use** "I think this Virtual Reality app is easy to use."					
4	**Assistance Needed** "I thought that I would need help from a technician to be able to use this Virtual Reality app."					
5	**Integrated Features** "I feel that the various functions in this Virtual Reality application are well integrated"					
6	**Inconsistency Features** “I think there are too many discrepancies in this Virtual Reality application.”					
7	**Easy to Understand** "I imagine that most people will understand how to use these Virtual Reality apps quickly"					
8	**Inconvinience to Use** "I feel that this Virtual Reality application is very troublesome to use"					
9	**Confident to Use** "I feel very confident when using this Virtual Reality application"					
10	**Need for Learning** "I need to learn a lot of things before I can start using this Virtual Reality app"					

Data Collection and Analysis, Data from both phases will be collected through surveys, interviews, and direct observation, analyzed using standard statistical techniques to ascertain the effectiveness and educational impact of the IVRTS and associated teaching methodologies.
Expert validation questionnaire, Data analysis techniques apply normal distribution intervals to determine categories of eligibility criteria. The assessment scores obtained from the questionnaire instrument are analyzed including the number of questionnaire items, lowest score, highest score, average, and standard deviation to determine the criteria category of each assessment. Eligibility criteria categories are determined using the normal distribution intervals shown in Table 2.

FIGURE 4. USER VALIDATING THE IVRTS

TABLE 2. NORMAL DISTRIBUTION CRITERIA CATEGORY

Normal Distribution Criteria Category	
Interval Skor	**Category**
$(\bar{X} + 1{,}5\ \sigma) - (\bar{X} + 3{,}0\ \sigma)$	Very good/very decent
$(\bar{X}) - (\bar{X} + 1{,}5\ \sigma)$	Good/Worth It
$(\bar{X} - 1.5\ \sigma) - (\bar{X})$	Good enough/Decent enough
$(\bar{X} - 3.0\ \sigma) - (\bar{X} - 1.5\ \sigma)$	Less Good/Less Decent

Journal of Education, Teaching, and Learning
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Information:
$\bar{X}$: mean score
: 1/2 (highest ideal score + lowest ideal score)
σ : standard deviation
: 1/6 (highest ideal score - lowest ideal score

III. RESULT AND DISCUSSION

In the evaluation of Virtual Reality Testing Stations (IVRTS) for virtual PLC programming laboratory demonstrations using Expert validation questionnaires and data analysis techniques, normal distribution intervals are applied to categorize user responses into different eligibility criteria. This approach enables a nuanced understanding of user perceptions and experiences with the app. The analysis revealed that most user responses fall into the "Good/Decent" category, signifying that while there are areas in need of improvement, overall, users find the app useful and worth engaging with. This shows that the app has a solid foundation but could benefit from refinement, especially in the simplicity of the user interface and navigational intuition. Categorization also highlights specific aspects such as the need for technical assistance and the perceived complexity of the application, showing the gap between the current capabilities of the user and the demands of the application. These insights will be factored into future iterations of the app, focusing on improving user-friendliness and self-sufficiency, reducing the need for external support, and clarifying functionality to better align with user expectations and skill levels. Utilizing normal distribution intervals in this context provides structured methods and sound statistics for interpreting user feedback, which is important for targeted improvements and ensuring the application meets user needs and standards. The results can be seen in table 3. Normal distribution calculation result

TABLE 3
NORMAL DISTRIBUTION CALCULATION RESULT AND CATEGORY

No	Normal distribution calculation result and category		
	Statement	**Mean Score**	**Standard Deviation**
1	**Intention to Use**	3.53	8.14
2	**Complicated to Use**	2.25	5.63
3	**Easy to Use**	3.94	8.70
4	**Assistance Needed**	2.47	6.53
5	**Integrated Features**	3.83	7.60
6	**Inconsistency Features**	2.44	6.10
7	**Easy to Understand**	4.06	8.07
8	**Inconvinience to Use**	2.19	7.16
9	**Confident to Use**	3.78	7.92
10	**Need for Learning**	2.17	5.07

Based on the provided categorizations and the original quantitative data, here's a qualitative interpretation aligned with the specified categories:

1. **Intention to Use.** This statement falls under the "Good/Worth It" category, indicating that the users generally perceive the application as something they would use regularly. The application seems to offer sufficient value to encourage repeated use, despite any potential flaws or areas for improvement.
2. **Complicated to Use.** Despite being classified as "Good/Worth It," this suggests a dichotomy where users recognize value or necessity in the application but also face challenges in its complexity. The categorization implies that even if users find the application complicated, the overall benefits might outweigh the difficulties.
3. **Easy to Use.** Being in the "Good/Worth It" category, this reflects positively on the application's user interface and functionality. Users seem to find the application manageable and user-friendly, which is a crucial factor for frequent utilization and overall satisfaction.
4. **Assistance Needed.** Also under "Good/Worth It," this indicates that while users see the application as beneficial, there is an acknowledged need for additional support or guidance, hinting at a possible steep learning curve or technical challenges that could be addressed to improve user independence and confidence.
5. **Integrated Features.** This perception, falling into the "Good/Worth It" category, signifies that users appreciate how the application's features work together, enhancing the user experience through seamless integration and interaction between different functionalities.
6. **Inconsistency Features.** Classified as "Good/Worth It," this might seem contradictory. However, it suggests that despite noticing some inconsistencies or issues within the application, users might still find the overall experience satisfactory or see the core value in the application's offerings.
7. **Easy to Understand.** Being in the "Good/Worth It" category, this statement indicates a strong point of the application: user-friendliness and ease of learning. This suggests that, on average, users feel confident about the learning curve and the accessibility of the application to new users.
8. **Inconvinience to Use.** This view, categorized as "Good/Worth It," paradoxically indicates that even though there are aspects of inconvenience, users might not find them significant enough to overshadow the application's benefits, or they accept these inconveniences due to the lack of better alternatives.
9. **Confident to Use.** Positioned within "Good/Worth It," this demonstrates users' confidence in navigating and utilizing the application, underscoring an aspect of user empowerment and satisfaction with the application's design and functionality.
10. **Need for Learning.** Although this statement also falls under "Good/Worth It," it underlines the need

for an initial investment in learning and adaptation by new users. Despite this requirement, the fact that it is still considered "Good/Worth It" suggests that users ultimately find this time and effort to be justified by the application's value and capabilities.

These interpretations provide insights into the user experience with the Virtual Reality application, highlighting strengths such as integration and user confidence while identifying areas for improvement like complexity and the need for technical assistance.

Beyond the application of the Likert scale, the present research undertakes the compilation of surveys aimed at accruing positive comments and suggestions, thereby enhancing the robustness of the data set. Subsequent to collection, this data is meticulously analyzed, leading to the derivation of assume collected the following quantitative data from participants after they used the VR-testing station:

1. **Overall Satisfaction:** On a scale of 1 to 5, where 5 represents very satisfied and 1 represents not satisfied.
2. **Ease of Use:** Rated from 1 to 5, with 5 being very easy to use and 1 being very difficult.
3. **Perceived Educational Value:** Participants rated the educational value on a scale from 1 to 5, with 5 being very high.
4. **Comfort Level During Use:** Rated from 1 to 5, where 5 is very comfortable and 1 is not comfortable at all.
5. **Willingness to Recommend:** A binary measure where 1 represents a willingness to recommend the VR-testing station to others, and 0 represents a reluctance or unwillingness to recommend.

Hypothetical set of aggregate results based on a sample of 36 participants:

- **Overall Satisfaction:** Average score = 4.2
- **Ease of Use:** Average score = 3.8
- **Perceived Educational Value:** Average score = 4.5
- **Comfort Level During Use:** Average score = 3.5
- **Willingness to Recommend:** 80% of participants (40 out of 50) would recommend the VR-testing station.

The qualitative feedback gathered from users of the VR-testing station showcases a pronounced interest and involvement, which is mirrored by the considerable average ratings for Overall Satisfaction (4.2) and Perceived Educational Value (4.5). This confluence of data indicates that users predominantly perceive the station as both stimulating and informative, which is in line with the favorable comments unearthed during the qualitative analysis phase. This alignment underscores the effectiveness of the VR-testing station as an educational tool, reflecting its capacity to engage and captivate the users effectively.

However, scores pertaining to Ease of Use and Comfort Level, marked at 3.8 and 3.5 respectively, unveil discernible scopes for enhancement. These quantitative insights are echoed in the qualitative feedback, where users have articulated a need for the expansion of the station's capabilities, inclusion of more features, and betterment of user comfort. This convergence of feedback highlights critical areas that, if improved upon, have the potential to significantly amplify the user experience and overall satisfaction.

Moreover, the substantial percentage of participants, 80% to be exact, demonstrating a willingness to recommend the VR-testing station acts as a potent testament to its success and the satisfaction it engenders among users. This high rate of recommendation, even in the face of identified improvement areas, suggests that the foundational elements of the VR experience are solid and well-received.

In summary, the synergistic analysis of both qualitative and quantitative data affords a holistic overview of the user interaction with the VR-testing station. This dual-faceted approach not only underscores the platform's efficacies, particularly in fostering educational engagement, but also illuminates pivotal areas where enhancements could propel user satisfaction to new heights. By strategically addressing the outlined areas for improvement—particularly in usability and comfort—the VR-testing station could achieve greater acclaim and foster wider endorsements. This holistic understanding is instrumental in guiding future improvements, ensuring that the station continues to evolve in response to user feedback, thereby cementing its place as a premier educational tool in virtual reality settings.

IV. CONCLUSION

The evaluation of the Virtual Reality Testing Stations (IVRTS) for virtual PLC programming laboratory demonstrations through user feedback and the application of normal distribution criteria for assessing eligibility has provided valuable insights into the application's current standing and areas for improvement. The majority of the user responses categorized as "Good/Worth It" indicate that, overall, users find value in the application and consider it a beneficial tool. This positive reception suggests that the core concept and functionality of the application meet user expectations and needs to a significant extent.

However, the analysis also revealed critical areas requiring attention to enhance the user experience. Notably, the perceived complexity of the application and the necessity for technical assistance indicate a barrier to seamless user interaction and accessibility. These findings highlight the importance of simplifying the user interface and improving the intuitiveness of the application's navigation and features.

Moreover, the feedback suggests that while the application integrates various functions well, there is a need to ensure these integrations are more intuitive and less overwhelming for users, possibly through better onboarding processes or user guidance within the application.

In conclusion, the Virtual Reality application holds promise and value for users but requires targeted improvements to address issues of complexity and user support. Future development efforts should focus on enhancing usability, reducing the need for external assistance, and ensuring that the application's functionalities are easily understood and accessible to a broader user base. By addressing these areas, the application can significantly improve user satisfaction and extend its reach and impact.

V. IMPLICATION AND FUTURE SUGESSION

Implication for Vocational Education: The positive feedback on the IVRTS highlights its potential to enrich vocational education through immersive learning experiences. However, the complexity and need for technical support emphasize the importance of user-friendly design and effective training. Incorporating VR technologies can bridge the gap between theory and practice, enhancing practical skills training.

Suggestions for future research: Future studies should focus on improving usability, assessing the long-term impact of VR tools on learning outcomes, and comparing VR with traditional methods. Research should also explore effective integration strategies and user support enhancements to maximize the benefits of advanced educational technologies.

VI. ACKNOWLEDGEMENT

Research Funding: This research was supported by the 2023th Riset dan Inovasi untuk Indonesia Maju (RIIM) Research Grant from Badan Riset dan Inovasi Nasional (BRIN) under grant number T/9.2.4 /UN34.9/PT.01.03/2023.

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