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Assessment Guidelines for Enhancing Student Engagement in Iot Via Active Learning

Garis Panduan Pentaksiran bagi Meningkatkan Penglibatan Pelajar dalam Internet Benda (IoT) melalui Pembelajaran Aktif

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ABSTRACT

The Internet of Things (IoT) presents significant challenges in education due to its complex and abstract nature, particularly when taught using traditional lecture-based approaches. This study proposes the integration of IoT-based active learning supported by a structured assessment framework to enhance student engagement and understanding at the foundation level. A quasi-experimental research design with a pretest and post-test control group is proposed to evaluate the effectiveness of hands-on IoT activities guided by the 6E instructional model. The study will compare students exposed to IoT-based active learning with those receiving conventional video-based instruction. The anticipated findings suggest that the proposed approach can improve students' conceptual understanding as well as their behavioural, cognitive, and emotional engagement. In addition, the development of a structured assessment guideline is expected to provide a systematic method for evaluating learning outcomes in IoT education. This study contributes to the advancement of technology-enhanced learning by offering a practical framework for integrating IoT and active learning in foundation-level curricula.

Keywords: Active Learning; Foundation; Internet of Things (IOT);Student Engagement

ABSTRAK

Internet benda (IoT) merupakan teknologi yang kompleks dan abstrak, yang sering menimbulkan cabaran dalam proses pengajaran dan pembelajaran, terutamanya apabila menggunakan pendekatan kuliah tradisional. Kajian ini mencadangkan penggunaan pembelajaran aktif berasaskan IoT yang disokong oleh rangka kerja penilaian berstruktur bagi meningkatkan penglibatan dan kefahaman pelajar di peringkat asasi. Kajian ini akan menggunakan reka bentuk kuasi-eksperimen dengan pendekatan pra dan pasca ujian kumpulan kawalan untuk menilai keberkesanan aktiviti hands-on IoT yang berpandukan model pengajaran 6E. Perbandingan akan dibuat antara pelajar yang mengikuti pembelajaran aktif berasaskan IoT dengan pelajar yang menerima pembelajaran konvensional berasaskan video. Dapatan yang dijangkakan menunjukkan bahawa pendekatan ini dapat meningkatkan kefahaman konsep serta penglibatan pelajar dari aspek tingkah laku, kognitif, dan emosi. Selain itu, pembangunan garis panduan penilaian berstruktur dijangka dapat menyediakan kaedah sistematik dalam menilai hasil pembelajaran bagi pendidikan IoT. Kajian ini menyumbang kepada pembangunan pembelajaran berasaskan teknologi dengan menyediakan kerangka praktikal untuk mengintegrasikan IoT dan pembelajaran aktif dalam kurikulum peringkat asasi.

Kata kunci: Pembelajaran aktif; Asasi; Internet benda; Penglibatan pelajar

INTRODUCTION

The Internet of Things (IoT) has emerged as a transformative technological paradigm with far-reaching technical, social, and economic implications. It refers to an interconnected ecosystem of devices that comprises sensors, hardware, and software that communicate through the internet to collect, process, and exchange data, enabling automated and intelligent system responses with minimal human intervention (Radouan Ait Mouha, 2021). IoT applications have expanded rapidly across domains such as smart homes, smart cities, industrial automation, transportation, and wearable technologies. From a systems perspective, IoT typically operates through four key layers: sensing, data transmission via internet gateways, edge-level processing, and cloud-based data storage and analytics (Laghari et al., 2024). Despite its growing relevance, the abstract and multi-layered architecture of IoT presents a significant challenge in educational contexts, particularly for novice learners who lack exposure to real-world implementations.

Active learning has gained recognition as an effective pedagogical approach in STEM education, emphasising student-centred and experiential learning processes. Unlike conventional lecture-based instruction, active learning engages students through interactive activities, collaborative tasks, and problem-solving exercises, thereby fostering deeper conceptual understanding and higher-order thinking skills (Kumar et al., 2024). Prior studies have demonstrated that active learning strategies, including gamification and hands-on activities, can significantly enhance student engagement, motivation, and learning outcomes. However, the effectiveness of such approaches is highly dependent on how they are designed, implemented, and assessed within specific disciplinary contexts.

Within the UTMSPACE foundation programme, IoT is introduced as a core component of the Computer Literacy course, where students are expected to acquire fundamental knowledge of IoT hardware, software, and applications. Nevertheless, the current instructional approach remains predominantly theoretical, with limited opportunities for students to interact with actual IoT systems. This creates a critical disconnect between conceptual understanding and practical application, leading to superficial learning and reduced student engagement. Furthermore, while previous studies have explored active learning and IoT education independently, there is a lack of structured frameworks that integrate IoT-based active learning with clearly defined assessment guidelines, particularly at the foundation level.

To address this gap, this study focuses on the design and development of an IoT-based active learning framework supported by a structured assessment guideline aimed at enhancing student engagement and conceptual understanding in foundation-level education. The study aims to establish a systematic instructional and assessment structure that can guide the implementation of IoT-based active learning activities. The primary aim of this paper is to develop a structured assessment guideline for IoT-based active learning using the 6E instructional model. Specifically, the objectives of this study are; (1) to design an IoT-based active learning activity framework suitable for foundation-level students, (2) to develop a structured assessment guideline to support the implementation and evaluation of IoT-based learning activities, and (3) to provide a practical instructional model that can be applied in future classroom implementation and empirical evaluation. By focusing on instructional design and assessment planning, this study contributes to the development of a practical framework for integrating IoT and active learning in foundation-level curricula and provides a foundation for future pilot testing and validation studies.

The remainder of this paper is organised as follows. Section 2 reviews relevant literature on active learning approaches in IoT education. Section 3 describes the methodology and design of the proposed IoT-based active learning framework. Section 4 presents the proposed IoT activity and assessment framework. Finally, Section 5 concludes the paper and outlines directions for future implementation and validation studies.

LITERATURE REVIEW

Active learning encompasses a range of instructional strategies that shift the focus from passive content delivery to student-centred engagement, where learners actively construct knowledge through participation in discussions, collaboration, and problem-solving tasks. In STEM education, particularly in computing and IoT-related disciplines, active learning plays a critical role in facilitating a deeper understanding of abstract and complex concepts. This is especially important in IoT education, where learners must comprehend multi-layered systems integrating both physical devices and digital processes. Previous studies have explored several forms of active learning applicable to computing education, including pair-based activities, card-based learning, gamification, project-based learning, and simulation-based approaches.

One of the foundational approaches is pair-based learning, as demonstrated in CS Unplugged activities. This method engages students in collaborative tasks using simple physical materials to represent computational processes. For example, algorithmic concepts such as sorting can be taught using card-based activities, allowing students to visualise logical sequences without coding (Mladenović et al., 2025). This approach is particularly effective for beginners as it reduces abstraction and supports conceptual understanding through peer interaction. However, its limitation lies in its inability to support more complex, system-level learning required in IoT contexts.

Similarly, card game-based learning enhances student engagement by embedding knowledge application within structured gameplay. Students are required to apply concepts, explain reasoning, and collaborate to solve problems. This method has been shown to strengthen understanding of technical topics such as parallel and distributed computing while promoting communication and teamwork (Srivastava & Smith, 2024). Compared to pair-based activities, card games introduce a higher level of engagement and interaction; however, they remain limited in addressing practical and hardware-oriented aspects of IoT systems.

A more comprehensive approach is gamification, particularly when integrated with the 6E instructional model (Engage, Explore, Explain, Engineer, Enrich, Evaluate). This model provides a structured learning sequence that combines hands-on activities with motivational elements such as points, leaderboards, and challenges. In IoT education, gamification has been implemented through smart home projects that enhance students' programming self-efficacy, IoT knowledge, and hands-on skills (Hsiao et al., 2023). Compared to simpler methods, gamification offers a more balanced approach by integrating cognitive engagement with motivation, making it highly suitable for foundation-level learners who require structured yet interactive learning environments.

Another widely adopted approach is project-based learning (PBL), which emphasises real-world problem-solving through collaborative projects. In IoT education, students are typically required to design and implement functional systems, such as smart environmental monitoring solutions. This approach promotes critical thinking, creativity, and teamwork, as students must analyse problems and develop practical solutions (Dai et al., 2024). While PBL provides deeper and more authentic learning experiences, it often requires more time, higher student autonomy, and greater instructional support, which may present challenges for early-stage learners.

At a more advanced level, 3D virtual simulation offers an immersive learning experience by allowing students to interact with simulated IoT environments. For instance, virtual smart city platforms enable learners to visualise data communication processes and system interactions in a controlled environment (Li et al., 2024). This approach is particularly useful when access to physical hardware is limited and supports system-level understanding. However, its implementation is often constrained by technological and resource requirements.

Overall, the literature suggests that each active learning approach offers distinct advantages depending on the learning objectives and context. Simpler methods, such as pair-based and card-based learning, are effective for foundational understanding, whereas more advanced approaches, such as project-based learning and simulation, support deeper application and system thinking. Among these, gamification integrated with the 6E model provides a balanced framework that combines structured learning, hands-on engagement, and motivational elements. Therefore, this study adopts gamification with the 6E model as the primary active learning strategy, as it aligns with the need to enhance both student engagement and conceptual understanding in IoT education. Based on the identified strengths of gamification integrated with the 6E model, this study adopts this approach as the core instructional strategy for the proposed intervention.

METHODOLOGY

This study proposes a quasi-experimental quantitative research design to evaluate the effectiveness of IoT-based active learning in enhancing student understanding and engagement. Specifically, a pretest and post-test control group design is proposed to compare learning outcomes between two groups of students. The experimental group participated in IoT-based hands-on active learning activities, while the control group received conventional instruction through video-based learning. This design enables the assessment of causal effects by measuring changes in students' performance and engagement before and after the intervention.

The participants of this study consisted of foundation students enrolled in the Computer Literacy course at UTMSPACE. The population included approximately 1000 students from three academic streams: Physical Science, Life Science, and Social Science. Based on the Krejcie and Morgan (1970) sampling table, a total of 278 students were selected as the sample size. A stratified sampling approach was employed to ensure representation across the different academic streams. The participants were then will be divided into two groups: an experimental group and a control group. Due to practical constraints in classroom settings, random assignment was not feasible; therefore, intact classes were used, which is consistent with quasi-experimental research practices.

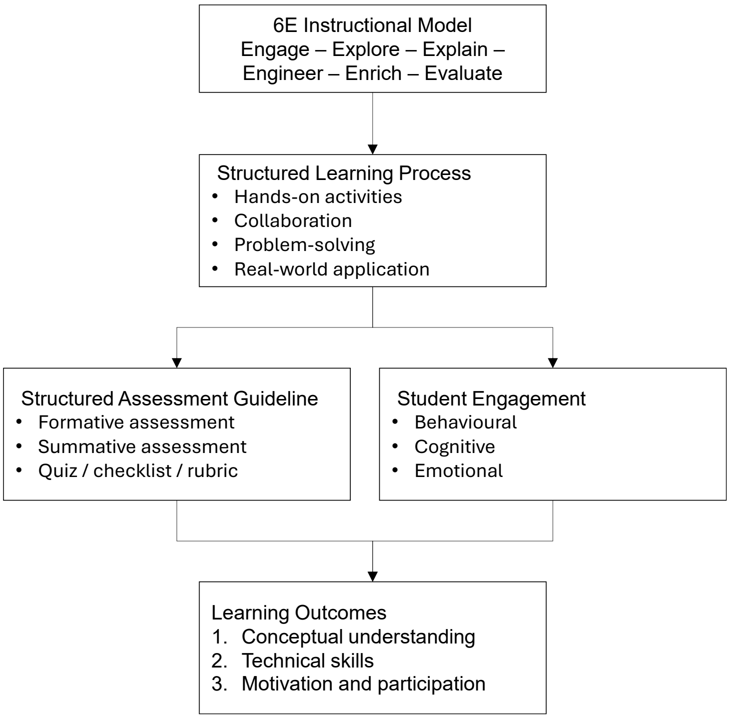
Figure 1 illustrates the proposed conceptual framework of the study. It shows how IoT-based active learning, guided by the 6E instructional model, is translated into structured learning activities and assessment guidelines to support student engagement and learning outcomes. The framework highlights the role of the assessment guideline as a key component linking instructional design with measurable learning and engagement outcomes.

Instructional Design and Intervention

The intervention involved the implementation of IoT-based active learning activities designed to provide hands-on exposure to IoT concepts. These activities were conducted after the delivery of theoretical content in class. The design of the activities was guided by active learning principles and incorporated elements of gamification based on the 6E model (Engage, Explore, Explain, Engineer, Enrich, Evaluate).

Students in the experimental group engaged in practical IoT tasks using Arduino-based kits, such as smart sanitiser systems, IoT door lock systems, and temperature and humidity monitoring systems. These activities required students to interact with hardware components, analyse system behaviour, and collaboratively solve problems. In contrast, the control group received instruction through video-based learning, where IoT concepts and applications were presented without hands-on interaction. This allowed for a clear comparison between active and passive learning approaches.

Figure 1: Conceptual framework illustrating the integration of IoT-based active learning, the 6E instructional model, and structured assessment guidelines to support student engagement and learning outcomes.



PROPOSED IoT ACTIVITY AND ASSESSMENT FRAMEWORK

This section presents the proposed IoT activity design and assessment framework developed for implementation in future classroom settings, focusing on three key components: (i) IoT activity guidelines and assessment plan, (ii) pre-test and post-test performance, and (iii) student engagement through IoT-based active learning. The discussion is framed based on expected trends informed by the study design and supported by existing literature.

IoT Activity Guidelines and Assessment Plan

The proposed study is expected to produce a structured assessment guideline for implementing IoT-based active learning in foundation-level education. The guideline will integrate instructional design with assessment components, ensuring alignment between learning objectives, activity execution, and evaluation criteria. The IoT activity will be designed based on the 6E instructional model (Engage, Explore, Explain, Engineer, Enrich, Evaluate), where each phase contributes to both learning and assessment. For instance:

1. Engage and explore phases will focus on initial interaction and conceptual exposure
2. Explain and engineer phases will emphasise problem-solving and hands-on implementation
3. Enrich and evaluate phases will assess understanding and application

The assessment plan is expected to include:

1. Formative assessment through observation of participation and task completion
2. Summative assessment through structured quizzes (pre-test and post-test)
3. Engagement measurement using questionnaire-based indicators

This structured approach addresses a key gap identified in the literature, where active learning is often implemented without clearly defined assessment frameworks. By linking IoT activities with measurable outcomes, the guideline is expected to support more systematic and replicable teaching practices.

Pre-test and Post-test Performance

It is anticipated that students in the experimental group (IoT-based active learning) will demonstrate a greater improvement in post-test scores compared to those in the control group (video-based learning). The hands-on interaction with IoT systems is expected to enhance students' ability to understand key concepts such as IoT architecture, components, and real-world applications. This expected improvement is consistent with previous findings that experiential learning enhances conceptual understanding by allowing students to directly interact with learning materials rather than relying solely on theoretical explanations (Kumar et al., 2024). In particular, the multi-layered nature of IoT systems encompassing sensing, communication, and data processing is better understood through practical engagement than through passive observation.

Furthermore, the pre-test and post-test comparison will provide insight into the learning gain achieved through the intervention. The framework is designed to support systematic evaluation of learning outcomes through structured pre- and post-assessment measures. In contrast, the control group may show only moderate improvement, reflecting the limitations of passive instructional methods in conveying complex technical concepts.

IoT-Based Active Learning and Student Engagement

The study is expected to reveal that IoT-based active learning significantly enhances student engagement across behavioural, cognitive, and emotional dimensions. Students participating in hands-on activities are likely to demonstrate:

1. Increased behavioural engagement through active participation and collaboration
2. Improved cognitive engagement through problem-solving and application of knowledge
3. Higher emotional engagement is reflected in interest and motivation

These anticipated findings align with prior studies indicating that active learning environments promote deeper engagement and improved learning outcomes compared to traditional methods (Kumar et al., 2024). The incorporation of gamification elements through the 6E model is also expected to further enhance motivation and participation, as supported by Hsiao et al. (2023), who found that gamified IoT learning improves both technical skills and learner engagement. Compared to simpler active learning approaches such as pair-based or card-based activities (Mladenović et al., 2025; Srivastava & Smith, 2024), the IoT-based hands-on activities in this study provide a more authentic and applied learning experience, enabling students to interact with real systems. This is expected to result in stronger engagement and more meaningful learning outcomes.

CONCLUSION

This study proposes the use of IoT-based active learning, supported by a structured assessment framework, to improve student engagement and understanding in foundation-level education. Traditional lecture-based methods are often insufficient for explaining complex IoT concepts, as they lack practical exposure. Therefore, this study introduces hands-on IoT activities guided by active learning principles and the 6E instructional model. The expected outcomes indicate that IoT-based active learning can enhance students' conceptual understanding as well as their behavioural, cognitive, and emotional engagement. By allowing students to interact directly with IoT systems, this approach helps bridge the gap between theory and practice, which is essential in STEM education. In addition, the inclusion of a structured assessment plan provides a clearer way to evaluate both learning outcomes and student engagement.

This study also offers practical value for educators, particularly in the foundation program, by providing a guideline for implementing IoT-based active learning. It supports the adoption of more interactive and experiential teaching approaches in line with current trends in STEM and TVET education. Overall, this study contributes by proposing an integrated framework that combines IoT, active learning, and assessment. Future work will focus on implementing the proposed approach in actual classroom settings to evaluate its effectiveness and long-term impact.

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