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Development and Usability Evaluation of PostHarvest EDU: An Interactive Practical E-Module for Postharvest Technology Courses

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ABSTRACT

The rapid advancement of digital technology has substantially transformed teaching and learning practices in higher education, particularly in the delivery of practical-based courses. In postharvest technology education, conventional printed laboratory manuals often lack interactivity and flexibility, which may constrain students' understanding of experimental procedures and reduce engagement during practical sessions. This study aimed to develop an interactive practical e-module, PostHarvest EDU, and to evaluate its usability among undergraduate students enrolled in a postharvest technology course. The e-module was developed using the ADDIE instructional design model, encompassing the phases of analysis, design, development, implementation, and evaluation. A quantitative usability evaluation was conducted with 59 undergraduate students who enrolled in Postharvest Technology Course at Sultan Idris Education University. Data were collected using a structured questionnaire assessing ease of navigation, content understanding, and interactivity in learning. Descriptive statistical analysis revealed very high mean scores for ease of navigation (M = 4.48), content understanding (M = 4.49), and interactivity in learning (M = 4.55). Overall, 98.3% of respondents reported positive learning experiences when using the e-module. These findings indicate that PostHarvest EDU demonstrates a high level of usability and effectively supports students' understanding of postharvest experimental procedures. The study concludes that interactive practical e-modules can serve as effective digital teaching resources for practical-oriented agricultural courses and contribute meaningfully to enhanced teaching and learning practices in higher education.

1. Introduction

Digital transformation has become a defining characteristic of contemporary higher education, driven by the growing demand for flexible, student-centred, and technology-enhanced learning environments. The integration of digital learning resources, including e-learning platforms and multimedia-based instructional materials, has been shown to enhance accessibility, learner

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engagement, and self-directed learning [16]. These developments are particularly pertinent to practical-based courses, where effective learning depends not only on theoretical understanding but also on students' ability to comprehend and apply experimental procedures.

Postharvest technology represents a critical domain within agricultural education, as it focuses on maintaining the quality, safety, and shelf life of horticultural produce after harvest. Ineffective postharvest handling practices can result in substantial qualitative and quantitative losses, thereby highlighting the importance of effective instructional strategies in this field [25]. Despite its significance, instruction in postharvest technology at the tertiary level continues to rely heavily on traditional pedagogical approaches, such as printed laboratory manuals and instructor-led demonstrations. These approaches often provide limited opportunities for repetition, reflection, and independent exploration, which may impede students' deeper conceptual understanding and skill development [24].

A growing body of literature indicates that interactive digital learning materials, particularly e-modules that integrate multimedia elements and learner-centred activities, can enhance motivation, engagement, and knowledge retention [18]. Within agricultural education, interactive e-modules are especially valuable as they enable students to revisit experimental content beyond restricted laboratory contact hours and accommodate diverse learning preferences. However, empirical research examining the development and usability of interactive practical e-modules specifically for postharvest technology courses remains limited. Accordingly, this study sought to develop an interactive practical e-module, PostHarvest EDU, and to evaluate its usability among undergraduate students in a postharvest technology course.

2. Methodology

This study adopted a research and development approach guided by the ADDIE instructional design model. There is five sequence phases in this model (**Figure 1**). The ADDIE model is a flexible instructional design framework that guides the systematic development of effective instructional materials which comprises five systematic phases: analysis, design, development, implementation, and evaluation [13,22]. The ADDIE model was selected due to its structured yet adaptable framework and its extensive application in the development of digital instructional materials in higher education contexts.

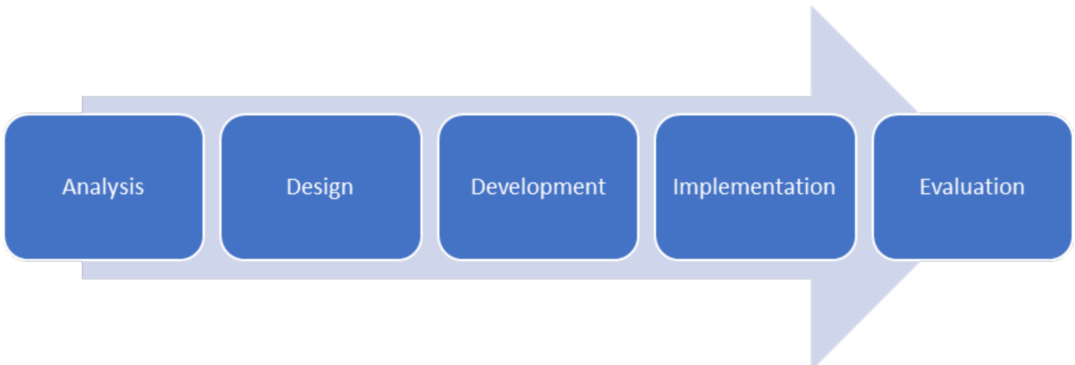

Fig. 1. Sequence of all five phases in The ADDIE Model (Rossett, 1987)

2.1 Analysis Phase

During the analysis phase, qualitative data were collected through structured interviews with one senior lecturer, one laboratory assistant, and three undergraduate students who had prior experience with the Postharvest Technology course. The interviews aimed to identify challenges associated with conventional practical sessions, limitations of existing instructional materials, and students' expectations regarding digital learning support. The interview data were analysed thematically and subsequently informed the design and development of the e-module.

2.2 Design and Development Phases

Based on the findings of the analysis phase, PostHarvest EDU was designed and developed using Google Sites as the primary platform. The e-module comprised six main sections: introduction, safety precautions, laboratory equipment, experiments, quizzes, and demonstration videos. The experimental content focused on three core postharvest experiments commonly conducted in the course: (i) comparison of fruit maturity indices based on physicochemical characteristics, (ii) harvesting and postharvest handling of leafy vegetables, and (iii) effects of 1-methylcyclopropene (1-MCP) on fruit physicochemical characteristics during storage.

To support meaningful learning, the e-module incorporated interactive features such as step-by-step procedural flowcharts, instructional and demonstration videos, self-assessment quizzes, chat-based assistance, and downloadable e-data sheets. These features were designed in accordance with constructivist and cognitive learning principles, emphasizing active engagement, structured information processing, and reduced cognitive load [1,3]. Consistent layout, intuitive navigation, and clear visual organization were prioritized to enhance usability and learning efficiency.

2.3 Implementation Phase

The implementation phase evaluated the performance of the PostHarvest EDU e-module in a real learning environment through a pilot study involving 30 students enrolled in the Postharvest Technology Course. The pilot study was conducted to assess usability, content clarity, and interactivity as well as to improve the quality and efficiency of the instrument items. Data were collected using a questionnaire administered via Google Form after students independently explored the e-module. The quantitative data were analyzed using Statistical Package for the Social Science (SPSS) by calculating the Cronbach's Alpha coefficient to determine whether the instrument data was acceptable. The coefficient values are shown in Table 1 below:

Table 1
Interpretation of Cronbach's Alpha coefficient value

No	Coefficient of Cronbach's Alpha	Reliability Level
1	More than 0.90	Excellent
2	0.80-0.89	Good
3	0.70-0.79	Acceptable
4	0.6-0.69	Questionable
5	0.5-0.59	Poor
6	Less than 0.59	Unacceptable

(Source: Mohd Arof et al., 2018)

2.4 Evaluation Phases

The evaluation phase involved a quantitative usability study conducted among 59 out of 73 undergraduate students enrolled in the Postharvest Technology course at Sultan Idris Education University. The sample size was determined based on Krejcie ang Morgan table. A structured questionnaire was administered to assess usability across three dimensions: ease of navigation, content understanding, and interactivity in learning. The collected data were analyzed using descriptive statistical techniques via the Statistical Package for the Social Sciences (SPSS). The survey contains five (5) sections that respondents need to answer which were section A: Demography of the respondents, section B: Usability of ease of navigating, section C: Usability of content understanding, section D: Usability of interactivity, and Section E: Usability consent.

3. Results

3.1 Analysis Phase

From the interview session with five informants, two main challenges were identified during practical sessions as shown in Table 2**.** The challenges were constraints in the use of printed laboratory manuals and constraints related to time and equipment. These issues reduced students' understanding and hands-on learning opportunities. Overall, these findings suggest that conventional printed laboratory manuals are inadequate in fully supporting effective practical learning.

Table 2
Summary of problems with conventional learning practical sessions

Code	Theme
• "Students don't bring the printed ones to the lab." – Informant 1 • "It only gives instructions without any diagrams." – Informant 2 • "The printed manual had too many word**...** lose interest and confused." – Informant 3 • "Usually, the printed manual that we provide is in a sentence. Okay, it doesn't have pictures. So, it's good to have pictures actually." – Informant 5	**Constraints in the Use of Printed Manuals** • Students do not bring the manual to the laboratory • The manual contains too much text • Lack of visuals/images • Students rely heavily on lecturers • Limited understanding of experimental procedures
• "During the experiment, it drags on for 3 to 4 hours." – Informant 3 • "Only 3 hours for experiments but still not enough." – Informant 2 • "Apparatus or equipment is not enough so we take turns." – Informant 3 • "Too many students … some students not to even do the practical session." – Informant 4 • "We have to take half an hour to just introduce the equipment first." – Informant 5	**Time and Equipment Problems During Practical Sessions** • Practical sessions take longer than the scheduled time • There is not enough equipment in the laboratory • Many students do not get hands-on experience

3.2 Design and Development Phases

PostHarvest EDU e-module was created using a combination of user-friendly and widely accessible digital tools. The main platform is Google Sites, which hosts the entire e-module in a structures format. A simple and clear menu structure was applied in the development of PostHarvest EDU to help users easily navigate the e-module. The main menu in this e-module consists of clearly labelled buttons such as Home, Safety Precaution, Laboratory Equipment, Quizzes, and Demonstration Video. These buttons allow users to immediately identify where to click based on their needs. Figure 2 shows the menu buttons are placed in a visible and accessible position, which is enabling users to move between sections smoothly when using the e-module.

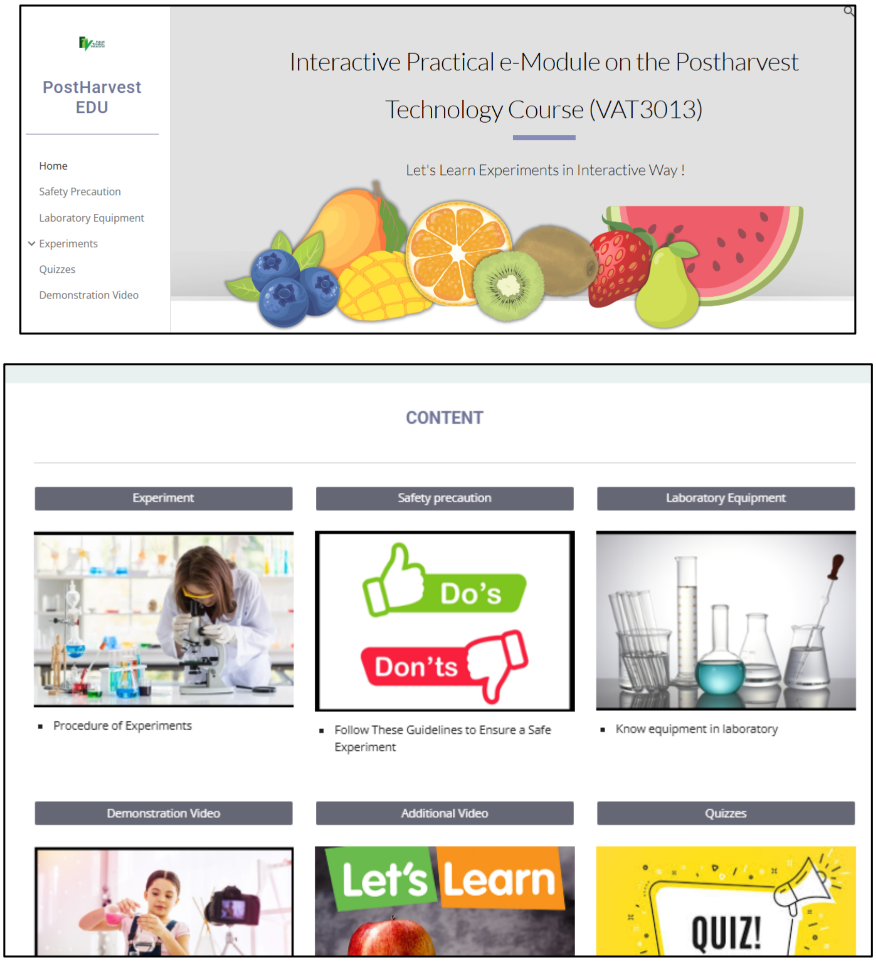

Fig. 2. Main page of PostHarvest EDU

The content in the e-module is logically structured. For example, the laboratory equipment page as shown in Figure 3 arranged with commonly used tools followed by calibration instructions to guide first-time users. In addition, to improve comprehension, the e-module presents experiments procedure in clear and sequential flowcharts as shown in Figure 4**.** The procedures used simple English and incorporates visual aids, including images and demonstration videos to enhance students' understanding. These experiments procedure were made by using Canva to create a visually appealing layout.

Fig. 3. Content provided inside laboratory equipment

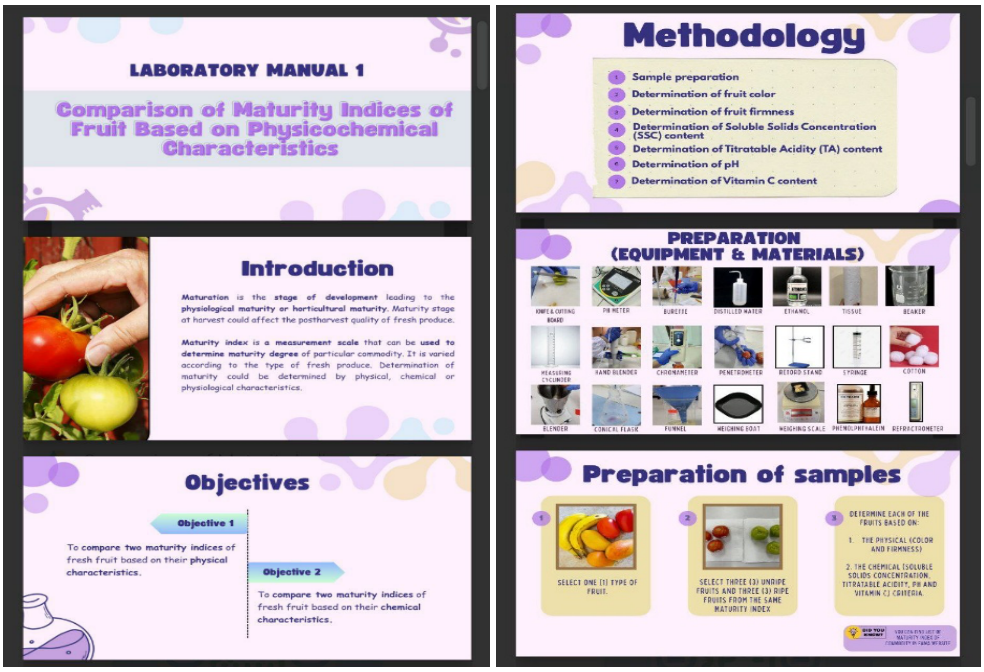

Fig. 4. Laboratory manual by using Canva

Furthermore, interactive elements such as videos, e-data sheet, AI chatbot and quizzes were integrated to promote active learning. Figure 5 represented a demonstration and additional videos to enhance procedural understanding, facilitate experiment implementation and increase students' knowledge. Meanwhile, self-assessment quizzes developed as shown in Figure 6 allow students to reflect their learning and test their knowledge. Other than that, a chatbot features also provided to act as real-time support and the interactive e-data sheet enables online data recording be more efficiently. Figure 7 illustrated an ai chatbot and e-data sheet developed in PostHarvest EDU e-module.

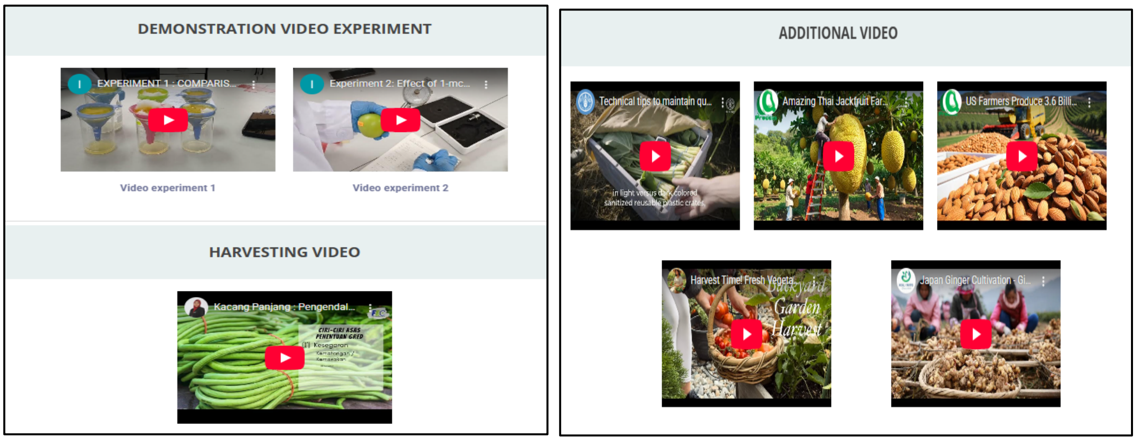

Fig. 5. Demonstration videos and additional video

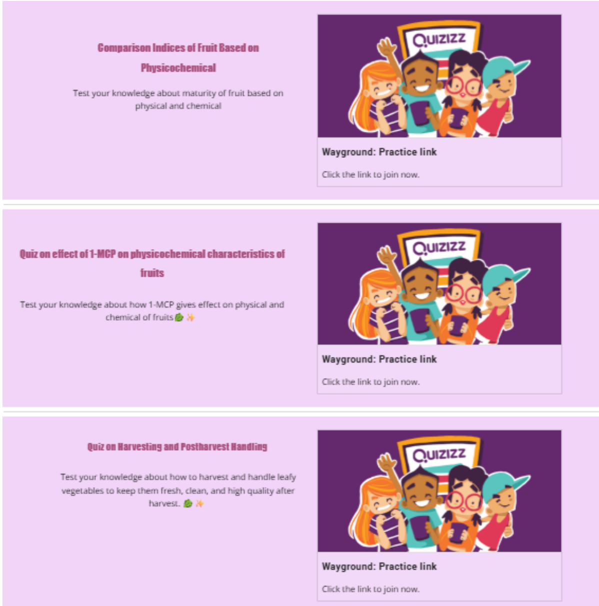

Fig. 6. Quizzes for self-assessment

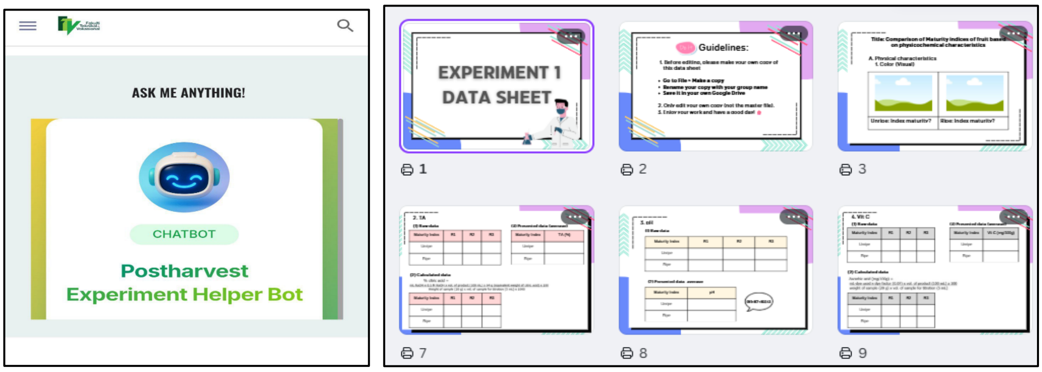

Fig. 7. AI Chatbot and E-data Sheet in PostHarvest EDU E-Module

3.3 Implementation Phase

The reliability analysis of the questionnaire demonstrated high internal consistency across all sections. Section B (Ease of Navigation) and Section C (Content Understanding) achieved good reliability, while Section D (Interactivity in Learning) was acceptable. Overall, the 15 items yielded a Cronbach's Alpha of 0.915, which was indicated excellent reliability. This proves that the questionnaire is effective and suitable for use in the actual study.

3.4 Evaluation Phase

The usability evaluation yielded consistently positive responses across all assessed dimensions. As shown in Table 3**,** the average mean score for each assessed aspect was presented. Ease of navigation recorded a mean score of 4.48, indicated that students were able to access and navigate the e-module with minimal difficulty. Content understanding achieved a mean score of 4.49 and this suggested that the instructional materials were clear, well-structured, and effective in supporting students' comprehension of postharvest experimental procedures. Interactivity in learning recorded the highest mean score of 4.55, which reflected strong student engagement with interactive components such as quizzes, videos, and e-data sheets.

Overall, in Table 4 shows 98.3% of respondents reported positive learning experiences when using PostHarvest EDU, demonstrating a very high level of usability and learner acceptance of the interactive practical e-module.

Table 3
Usability evaluation of PostHarvest EDU

Usability Dimension	Mean Score
Ease of Navigation	4.48
Content Understanding	4.49
Interactivity in Learning	4.55

Legend: Mean scores were interpreted using a five-point Likert scale (1 = strongly disagree, 5=strongly agree).

Table 4
Interpretation data for usability consent

Item	Question	Yes		No	
		Frequency	Percentage (%)	Frequency	Percentage (%)
E1	I am satisfied with the overall usability of this PostHarvest EDU e-module.	59	100	0	0
E2	This e-module meets my expectations as an effective learning tool.	59	100	0	0
E3	This e-module could be access anytime and anywhere.	58	98.3	1	1.7
E4	User have a positive experience while using this e-module.	58	98.3	1	1.7

4. Discussion

The Systematic Integration of the ADDIE Design Model in Practical Science Education

The exceptionally high usability and acceptance ratings achieved by PostHarvest EDU demonstrate that the systematic integration of the ADDIE framework is highly effective for designing digital practical learning resources. Rather than developing a digital platform without empirical justification, this study began with a qualitative front-end needs assessment. This initial analysis identified critical manual-based and logistical bottlenecks that directly informed the development of the e-module.

This structured approach aligns with recent studies showing that the ADDIE model ensures strong alignment between learner requirements, pedagogical content design, and system development. For instance, research on an interactive e-module for Bugis-Makassar ethnobotany reported a student usability score of 84.92%, attributing this success to the structured execution of the ADDIE model [14]. Similarly, the development of the Aquaponic Mini Model Learning Aid Kit in aquaculture courses used ADDIE's iterative evaluation loop to successfully align content with user requirements, improving students' practical skills and concept mastery [7].

By incorporating systematic validation and pilot testing during the Implementation phase, the research team ensured that the survey was highly reliable (alpha = 0.915), producing a consistent and valid assessment of student perceptions. Formative evaluation loops within each ADDIE phase allowed the team to iteratively refine interface layouts, visual structures, and interactive functions, avoiding the design failures often found in platforms developed without user-centered focus [22].

Platform Feasibility and Google Sites as a Democratic E-Learning Solution

The selection of Google Sites as the primary platform for PostHarvest EDU represents a highly practical and democratic approach to delivering digital instruction. Traditional e-learning implementations are often hindered by the high licensing costs of proprietary learning management systems (LMS) or the programming skills required to build custom educational platforms [8]. Usability evaluations of online tools in technical institutions often reveal a significant gap between instructor and student perceptions [6]. While lecturers may find complex platforms highly useful, students frequently report lower satisfaction due to non-intuitive interfaces and a lack of immediate support.

Google Sites addresses these concerns by providing an intuitive, responsive, and zero-cost environment that requires no programming expertise. This platform is highly efficient in data and device storage usage, making it exceptionally accessible for students using smartphones and mobile browsers. Recent research by Siska [14] demonstrates that Google Sites-based digital media significantly support independent learning in hybrid higher education contexts, achieving an expert content validity of 92.5%, a student practicality rating of 88.6%, and an independent learning score of 86.4%.

Furthermore, integrating multi-modal elements on Google Sites has been shown to improve critical thinking, problem-solving skills, and academic motivation in complex subjects such as physics and calculus. For example, studies by Susanti [19] on physics e-modules achieved a student perception score of 85.48%, confirming that Google Sites-hosted materials effectively accommodate diverse learning styles and improve concept retention.

By organizing postharvest experimental workflows, safety procedures, and calibration guidelines on an accessible Google Sites platform, PostHarvest EDU enables continuous, self-paced learning beyond the physical classroom. This flexible structure directly addresses the time and equipment limitations identified in conventional laboratory sessions.

Cognitive Load Management and the Role of Interactive Pre-Lab Scaffolding

The high mean score for content understanding (4.49) indicates that PostHarvest EDU successfully manages the cognitive demands associated with complex scientific experiments. Grounded in Cognitive Load Theory (CLT), human cognitive architecture is characterized by a working memory with strictly limited capacity and duration, and an unlimited long-term memory where cognitive schemas are constructed. During instructional activities, the total mental workload of a learner can be mathematically modeled as:

$$CL_{\text{total}} = CL_{\text{intrinsic}} + CL_{\text{extraneous}} + CL_{\text{germane}}$$

where CL_{total} represents the total cognitive load, $CL_{intrinsic}$ is the intrinsic load dictated by the natural complexity of the material, $CL_{extraneous}$ is the extraneous load caused by poor instructional design, and $CL_{germane}$ is the beneficial mental effort dedicated to schema construction [20].

Traditional, text-dense laboratory manuals present protocols in a dense, descriptive format. According to Sortwell *et al.*, [15], when students attempt to process these paragraphs while simultaneously operating physical equipment and adhering to safety rules, their limited working memory is rapidly overwhelmed by extraneous cognitive load $CL_{extraneous}$. This overload causes cognitive disorientation, making it difficult for students to construct correct mental schemas.

PostHarvest EDU directly reduces $CL_{extraneous}$ by replacing long blocks of text with Canva-designed visual flowcharts and sequential diagrams. This approach aligns with Mayer's Cognitive Theory of

Multimedia Learning, which states that learners build deeper mental representations when visual and verbal channels are processed in parallel [2].

Furthermore, providing instrument calibration guidelines and demonstration videos on the platform acts as a high-quality pre-laboratory scaffold. These resources allow students to review the correct procedures, safety precautions, and equipment-handling techniques before attending the physical laboratory session. Through early exposure to calibration steps, students can develop a clearer understanding of how instruments should be prepared, adjusted, and used accurately during practical work. This is particularly important in laboratory-based learning, where students are often required to follow precise procedures while managing time, equipment, and safety requirements.

The use of demonstration videos further strengthens students' procedural readiness by allowing them to observe each step visually before performing the task themselves. Multimedia learning theory suggests that students learn more effectively when verbal explanations are supported by relevant visual information, as this can reduce unnecessary cognitive processing and support better understanding of complex procedures [9]. In addition, pre-laboratory digital resources have been reported to help students manage cognitive load and improve their preparation for hands-on activities, especially when the resources are structured to guide students through the expected procedures before the actual laboratory session [10].

In this context, the platform provides students with an opportunity to become familiar with laboratory instruments before direct use. Calibration guidelines help students understand the purpose of calibration, the correct sequence of adjustment, and the importance of accuracy in data collection. Meanwhile, demonstration videos can show practical details that are difficult to explain through written instructions alone, such as hand positioning, equipment setup, reading measurement scales, and common procedural errors. As a result, students may enter the laboratory with greater confidence, lower anxiety, and better readiness to complete practical tasks independently.

While virtual simulation tools can sometimes widen the performance gap between high-achieving and low-achieving students due to differing baselines of prior knowledge, a hybrid model that uses pre-lab e-modules to prepare students for physical hands-on experiments establishes a stable baseline of understanding, ensuring that all students can focus on core scientific concepts.

Conversational Agents and the Transition Toward Interactive Digital Scaffolding

The exceptionally high score for Interactivity in Learning (4.55) highlights the value of the interactive features integrated within PostHarvest EDU, particularly the self-assessment quizzes, digital data sheets, and the AI chatbot. In online and hybrid environments, a lack of immediate support often causes a "break in presence," leading to student frustration, confusion, and a loss of academic interest [15]. Integrating an artificial intelligence chatbot as a Conversational Pedagogical Agent (PCA) addresses this challenge by providing real-time, 24/7 instructional scaffolding.

Unlike traditional, rigid, rule-based search engines, modern conversational agents leverage natural language processing (NLP) to understand student queries and deliver personalized feedback aligned with the student's immediate learning needs [11]. This responsive tutoring is highly valuable in scientific laboratories, enabling students to instantly check equipment operation steps, verify safety parameters, and clarify calculations.

By integrating a chatbot alongside downloadable e-data sheets, PostHarvest EDU creates an interactive, supportive learning space. This configuration helps students complete postharvest experiments successfully, reinforcing their conceptual understanding and procedural skills with minimal direct supervisor intervention.

5. Conclusions

This study concludes that PostHarvest EDU is a usable and effective interactive practical e-module for postharvest technology courses at the undergraduate level. The high usability ratings across all evaluated dimensions provide empirical support for the integration of interactive e-modules as complementary teaching resources in practical-oriented agricultural education. From an instructional perspective, the e-module offers lecturers a structured and flexible digital tool to enhance laboratory teaching, while enabling students to engage in independent, self-paced learning beyond formal contact hours.

Future research may extend this work by examining the impact of interactive practical e-modules on students' learning outcomes, skill acquisition, and long-term knowledge retention through experimental or quasi-experimental research designs. Additionally, comparative studies across institutions or disciplines could further elucidate the broader applicability of such digital learning interventions.

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Conflict of Interest Statement

The authors declare that there is no conflict of interest regarding the publication of this paper. No financial support, grants, or other forms of compensation were received that could have influenced the outcomes of this work. The research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Data Availability Statement
All data generated or analyzed during this study are included in this published article. Additional datasets are available from the corresponding author upon reasonable request. Where applicable, publicly available datasets used in the study are cited in the references

Ethics Statement
This study was conducted in accordance with the ethical standards of the institutional and/or national research committee. Ethical approval was obtained where required, and informed consent was obtained from all participants involved in the research.

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