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Enhancing Health Technology Awareness Through Medical Equipment Prototyping Workshops for Vocational Students in Rural Setting

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ABSTRACT

Raising awareness of health technology among students in underserved regions is crucial to building future-ready healthcare ecosystems. This community engagement project aimed to enhance vocational high school students' in rural setting understanding of medical device prototyping through a hands-on workshop on IoMT-based technologies using NodeMCU. A pre- and post-workshop assessment was conducted using the Health Technology Awareness Index (HTAI) and a participant satisfaction questionnaire. Initial findings revealed that 73.3% of students fell into the low and very low awareness categories. After the intervention, participants demonstrated a statistically significant improvement in awareness scores ($p < 0.01$), with an average increase of 21.4%. Satisfaction data indicated that 56.7% of participants were satisfied with the workshop, especially regarding the clarity of materials and prototype practicality. These results highlight the effectiveness of practical, locally grounded health tech workshops in narrowing the digital divide, suggesting a scalable model for future initiatives.

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INTRODUCTION

Health technology has emerged as a cornerstone in modern healthcare systems, enabling improved diagnostics, monitoring, treatment, and overall health service delivery. In particular, its potential to enhance healthcare accessibility and quality in underserved or rural areas has become increasingly apparent. Despite its transformative potential, awareness and literacy related to health technology remain critically low among youth populations in many low- and middle-income countries (LMICs). This lack of exposure is especially concerning in vocational education settings, where students are often poised to enter technical or health-adjacent professions but are rarely equipped with the competencies needed to engage with modern medical technologies. These students represent a vital yet underdeveloped segment of the future healthcare technology workforce.

Addressing this awareness and knowledge gap is not merely a matter of enhancing individual employability; it is fundamental to fostering long-term digital equity and national health resilience. As nations strive to implement digital health strategies and prepare their health systems for the integration of technology-driven solutions, early-stage educational interventions become indispensable. The incorporation of health technology into pre-tertiary education serves as both an empowerment tool for students and a strategic investment in national capacity building. Rodriguez et al. (2023) argue that inclusive, human-centered innovation in health technology must engage youth and community members in the early stages of design and education to create solutions that are contextually appropriate and equitable.

Experiential learning strategies offer a proven pathway for achieving these goals. Approaches that involve hands-on prototyping and problem-based activities have demonstrated efficacy in enhancing student motivation, comprehension, and retention of complex technical concepts (Ain, Rulaningtyas, & Putra, 2021). Within the context of health technology, microcontroller-based systems such as Arduino and NodeMCU provide a highly adaptable and affordable platform for introducing students to core concepts of biomedical instrumentation and the Internet of Medical Things (IoMT). These platforms allow learners to directly interact with sensors, wireless modules, and user interface components, thus demystifying how real-world medical devices are built and function. Auflem (2023) emphasizes that the act of prototyping itself fosters deeper conceptual understanding, creativity, and iterative thinking, particularly when learners can test, fail, and refine their designs in a supportive environment.

The importance of such technical exposure extends beyond individual learning outcomes. Mukherjee, Era, and Roy (2024) highlight that the lack of familiarity with medical device safety and usability remains a significant barrier to healthcare innovation, even among professionals. Introducing these concepts early through structured education and workshops can nurture a generation that is not only technologically literate but also safety-conscious and patient-centered. Moreover, these learning experiences often promote higher-order skills such as systems thinking, teamwork, and communication, which are increasingly valuable in interdisciplinary healthcare environments.

Evidence also suggests that short, intensive educational interventions can yield significant gains in awareness, attitudes, and intentions related to health technology use. Tam et al. (2017) and Lupton (2021) observed that brief workshops and community-based technology training improved understanding, reduced perceived stigma, and increased willingness to engage with digital health tools across age groups. Among youth, especially in developing regions, such interventions help build a critical foundation for future participation in digital health ecosystems. Jahan et al. (2020) and Manyazewal et al. (2021) further emphasize the need for accessible, community-anchored programs to bridge digital divides and democratize access to health innovations.

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Despite these promising developments, few studies have systematically measured the impact of workshop-based learning on health technology awareness in rural vocational settings. Most interventions focus on university or clinical trainees, leaving a gap in understanding how earlier-stage learners engage with and benefit from such programs. Moreover, while satisfaction surveys are often included in program evaluations, few use validated indices to quantify awareness or educational outcomes in this domain.

To address this research gap, the present study evaluates a structured, community-based educational intervention focused on the development of simple IoMT-enabled medical device prototypes using NodeMCU. The workshop was conducted in a rural vocational school setting and included theoretical instruction, guided prototyping sessions, and interactive discussions on health technology applications and safety. The study employed two key instruments for evaluation: the Health Technology Awareness Index (HTAI), adapted from prior awareness frameworks (Pai & Alathur, 2019; Mukherjee et al., 2024), and a participant satisfaction survey assessing delivery, materials, and engagement.

The objectives of this study are threefold which to quantitatively assess changes in students' awareness of health technology using the HTAI, to evaluate satisfaction with the workshop in terms of perceived relevance, engagement, and instructional quality, and to explore the viability of university–vocational school collaboration as a scalable model for early-stage digital health education. These goals are situated within broader efforts to build capacity for digital health adoption and innovation in low-resource environments, while also reinforcing the tridharma principles of Indonesian higher education through community service, teaching, and applied research.

By investigating the educational, attitudinal, and experiential impacts of this workshop, the study aims to contribute to both the scholarly discourse on inclusive health technology education and to practical models for implementation in other similar settings. The findings are expected to inform future curriculum development, community engagement strategies, and policy frameworks aimed at advancing digital health literacy among the next generation of healthcare technologists.

METHOD

Research Design

This study adopts a participatory action research design, integrating community service and educational intervention to enhance vocational students' awareness of health technology through hands-on prototyping. The method aligns with the human-centered approach recommended by Rodriguez et al. (2023), in which learners actively participate in both conceptual and practical activities, ensuring deeper contextual understanding and long-term retention. This study did not involve any sensitive personal data, clinical procedures, or biomedical interventions that would typically require ethical approval. The workshop was conducted as part of a community education and outreach initiative involving vocational high school students, with all activities focused on non-invasive, non-clinical educational content. Participation was voluntary and coordinated with school authorities, and no identifiable personal data was collected.

Participants and Setting

The intervention was conducted at SMKN 1 Tambang, a vocational high school located in a rural area of Kampar District, Riau, Indonesia, on August 4, 2025. The workshop involved 30 vocational students

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from the electronics and electrical engineering departments. They were selected based on their interest and basic knowledge of electronics.

The facilitators consisted of three lecturers from the Bachelor of Applied Biomedical Engineering Program at Institut Kesehatan dan Teknologi Al Insyirah (IKTA) and seven final-year students, who previously developed their own medical prototype projects during the 2024–2025 capstone design course.

Workshop Preparation and Implementation

Planning the Workshop Requirements and Identifying Target Participants

The planning phase involved coordination with the vocational school, defining participant criteria, and identifying workshop materials and equipment needed.

Developing Medical Equipment Prototypes as Workshop Materials

Lecturers and university students developed low-cost, functional prototypes using Arduino and NodeMCU platforms. The prototypes included basic tools such as heart rate sensors, temperature monitors, and fall detection systems, inspired by previous research emphasizing simplicity and effectiveness in student engagement (Auflem, 2023; Ain et al., 2021).

Designing the Workshop Modules

A structured workshop module was developed to support the cognitive and psychomotor learning objectives of the program. The module integrated theoretical concepts with applied technical activities to ensure participants not only understood the importance of health technologies but also acquired the basic skills needed to prototype medical devices using microcontroller platforms.

The materials were divided into two primary sections:

A. Introductory Theoretical Content

This section introduced the foundational concepts in health technology and biomedical instrumentation, including:

- Definition and Scope of Health Technology

  Introducing health technology as a multidisciplinary field that applies engineering principles to solve health problems, including examples such as wearable devices, patient monitors, and diagnostic tools.

- Classification of Medical Devices

  Discussion on device risk classes (e.g., Class I–III) and examples of devices at each level of complexity and regulatory scrutiny.

- Microcontroller Applications in Healthcare

  Overview of how platforms like Arduino and NodeMCU are used in the development of low-cost diagnostic and monitoring devices.

- Digital Health Trends

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A brief look at telemedicine, IoT in healthcare, and mobile health apps, contextualized for vocational students.

- Health Device User Needs and Safety Principles

  Introduction to user-centered design, basic safety requirements, and the importance of usability and reliability in device development.

B. Hands-On Technical Activities

To bridge theory with practice, the second part of the module focused on step-by-step prototyping exercises, including:

- Introduction to Arduino/NodeMCU Hardware
  - Understanding pin layout and connections
  - Installing Arduino IDE and basic code uploading
- Sensor Integration
  - Using sensors such as:
    - ✓ Heart rate (e.g., MAX30100 or pulse sensor)
    - ✓ Temperature (e.g., LM35 or DS18B20)
    - ✓ Movement/Fall detection (e.g., MPU6050)
- Coding and Logic
  - Writing simple logic to read sensor data
  - Displaying output via serial monitor or OLED screens
- Assembly and Troubleshooting
  - Breadboard wiring
  - Common errors and debugging
- Final Prototype Testing
  - Functionality verification
  - Presentation and peer review

Each student group was guided by a university student mentor, and participants received a printed workbook containing:

- Slide summaries of the theory
- Pin diagrams and wiring examples
- Sample Arduino codes with annotations
- Worksheet for prototype documentation and reflection

The structure of the module ensured that students could connect the conceptual value of medical technology with practical implementation, supporting experiential learning objectives in line with engineering education best practices (Auflem, 2023; Ehteshami et al., 2013).

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FIGURE 1. Workshop Module

Preparing Pre-Test and Post-Test Instruments

To systematically measure the effectiveness of the workshop, two evaluation instruments were developed: the Health Technology Awareness Index (HTAI) and a Participant Satisfaction Survey. These instruments were used to assess the cognitive and affective impact of the intervention on vocational students.

The HTAI was designed as a structured questionnaire to assess the pre- and post-workshop awareness levels of participants regarding health technology. The instrument was adapted from established awareness and digital literacy tools (Pai & Alathur, 2019; Mukherjee et al., 2024), and was customized to fit the context of vocational-level education and the workshop content.

The instrument consisted of 20 items, categorized into four dimensions:

- Basic Awareness

  Assessed familiarity with existing health technologies, such as wearable devices and mobile health applications.

- Functional Understanding

  Measured the ability to explain how common technologies (e.g., sensors, medical devices) operate and interact with users.

- Perceived Importance and Future Relevance

- Evaluated the participants' views on the significance of health technology in present and future healthcare systems.

- Personal Use and Advocacy

  Captured behaviors and attitudes toward adopting and promoting health technologies in personal or community contexts.

Each item was rated on a 5-point Likert scale ranging from 1 (Strongly Disagree) to 5 (Strongly Agree). The total score (out of 100) was then used to classify participants into five levels of awareness: Very Low, Low, Moderate, High, and Very High. This index provided a quantitative baseline and outcome measure for the workshop's impact on participants' conceptual understanding and perception of health technology.

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In addition to awareness, a 10-item Participant Satisfaction Survey was administered post-workshop to assess the perceived quality and effectiveness of the learning experience. This instrument covered multiple aspects of the workshop, including:

- Clarity of instruction and delivery by lecturers
- Relevance and usefulness of learning materials
- Engagement and accessibility of prototype activities
- Support and responsiveness of student facilitators
- Overall workshop organization and time allocation

Participants responded using the same 5-point Likert scale, allowing for both item-level insights and the calculation of an average satisfaction score. Responses were interpreted using categorized satisfaction levels (Very Satisfied, Satisfied, Neutral, Dissatisfied) to identify specific strengths and areas for improvement in the program delivery.

The Health Technology Awareness Index (HTAI) instrument used in this study was designed based on established models of technology awareness surveys and adapted from previous research such as Pai and Alathur (2019) and Mukherjee et al. (2024), ensuring content validity aligned with current frameworks in health technology education. The instrument includes Likert-scale items that assess knowledge, perception, and readiness toward medical technology and IoMT. To establish internal consistency, a pilot test was conducted before the main workshop, and the reliability of the HTAI was evaluated using Cronbach's alpha, which yielded a value above 0.8, indicating high reliability. While this instrument has not been formally standardized, its structure was informed by comparable tools used in digital health literacy studies, and the use of both pre- and post-intervention testing strengthens its construct validity. Continued refinement and larger-scale application of the HTAI will help further establish its robustness as a tool for evaluating awareness in similar educational interventions.

Together, the HTAI and the satisfaction survey offered a comprehensive evaluation framework that integrated learning outcomes with learner experience, ensuring that both cognitive gains and emotional engagement were captured and analyzed.

Conducting the Workshop

The one-day workshop began with a lecture on health technology and its relevance in daily life. Students were then divided into small groups, each mentored by a university student to build and test a simple health device. This participatory method is rooted in experiential learning theory and supports practical skill development (Ehteshami et al., 2013).

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FIGURE 2. Workshop Activity

Analyzing the Health Technology Awareness Index (HTAI)

The data collected from the workshop participants consisted of pre-test and post-test responses using the Health Technology Awareness Index (HTAI) and a post-intervention participant satisfaction questionnaire. For the HTAI instrument, descriptive statistics such as mean, median, and standard deviation were calculated for each item to provide an overview of the participants' awareness levels before and after the workshop. To assess the effectiveness of the intervention, a paired sample t-test was conducted to evaluate whether the differences between pre- and post-test scores were statistically significant. This inferential statistical analysis helps determine whether the observed improvements in health technology awareness were likely due to the workshop and not by chance.

In addition, effect size (Cohen's d) was computed to measure the magnitude of the improvement. A moderate to large effect size would further support the practical significance of the intervention. The internal consistency of the HTAI instrument was examined using Cronbach's alpha to ensure reliability across multiple items, with values exceeding 0.8 considered acceptable.

For the participant satisfaction data, Likert-scale responses were analyzed using frequency distribution and mean scores for each component such as speaker clarity, relevance of materials, hands-on activity usefulness, and overall experience. Open-ended responses, if any, were subjected to basic thematic analysis to extract recurring themes and participant suggestions. Together, these quantitative and qualitative approaches provided a comprehensive picture of both the learning outcomes and participant experiences associated with the health technology prototyping workshop.

Formulating Recommendations for Future Programs

The final stage involved reflecting on participant feedback and workshop outcomes to suggest improvements and potential scale-up strategies.

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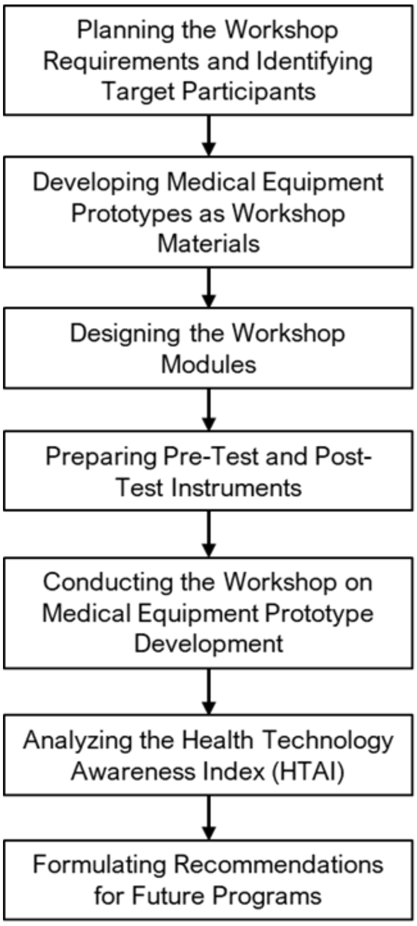

FIGURE 3. Workshop Process Flow

Furthermore, several limitations must be acknowledged. First, the study employed a quasi-experimental design without a control group, which makes it difficult to isolate the intervention's effects from external influences. Second, participants were drawn from a single school in a rural Indonesian setting, potentially limiting the applicability of the results to other demographic or geographic contexts. Third, self-reported awareness data using Likert scales may be subject to response bias or social desirability effects. Although triangulated with satisfaction metrics, no qualitative interviews or long-term follow-ups were conducted to assess sustained impact. Addressing these biases in future studies could strengthen the validity and scalability of this intervention model.

RESULT

This section presents the outcomes of the workshop as measured by two primary instruments: the Health Technology Awareness Index (HTAI) and a Participant Satisfaction Survey. Both were administered to the 30 vocational students before and after the intervention to assess the impact of the workshop on their awareness and perception of health technology.

Health Technology Awareness Index (HTAI) Results

The HTAI instrument consisted of 20 items across four dimensions: Basic Awareness, Functional Understanding, Perceived Importance, and Personal Use & Advocacy. Each item was rated on a 5-point

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Likert scale. The analysis revealed a clear improvement in awareness levels after the workshop. Table 1 shows the distribution of participants across awareness categories before and after the workshop.

TABLE 1. Distribution of participants across awareness categories before and after the workshop

Awareness Level	Pre-Test (n)	Post-Test (n)
Very Low (≤39)	10	2
Low (40–54)	15	7
Moderate (55–69)	5	10
High (70–84)	0	9
Very High (≥85)	0	2

The results indicate a notable upward shift in awareness categories after the intervention, with the majority of participants progressing from the “Very Low” and “Low” categories to “Moderate” and “High” awareness. This improvement supports previous findings that hands-on, contextualized learning enhances technology literacy in students (Tam et al., 2017; Lupton, 2021).

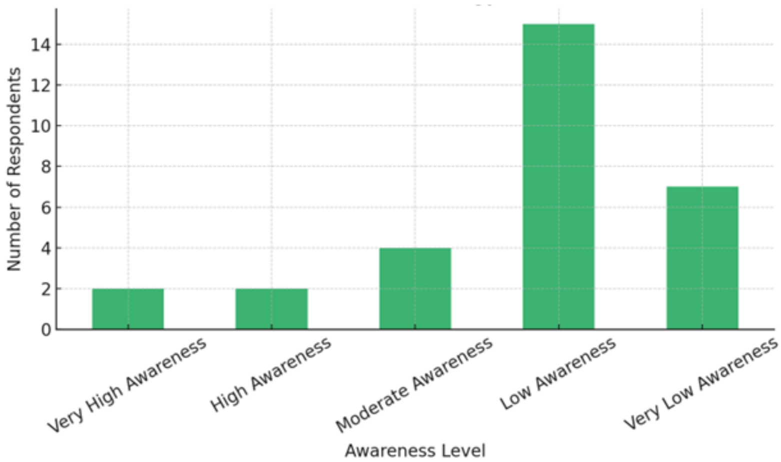

FIGURE 4. Distribution of Health Technology Awareness Levels

As shown in Figure 4, the majority of participants entered the workshop with limited prior knowledge of health technology, with 15 students categorized under Low Awareness and 7 students under Very Low Awareness. Only a small number of students demonstrated Moderate (4), High (2), or Very High Awareness (2), indicating that most vocational students had minimal exposure to or understanding of health technologies before the intervention. This distribution underscores the relevance and necessity of the workshop, which was specifically designed to introduce foundational concepts and practical experience in medical device prototyping for learners with limited baseline awareness.

Participant Satisfaction

A post-workshop satisfaction survey measured participant responses to ten indicators related to the quality of instruction, content relevance, prototype engagement, and facilitator support. The average satisfaction score across all items was 3.9 out of 5, indicating a generally positive reception of the program.

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TABLE 2. Participants Satisfaction Result

Satisfaction Level	Frequency (n)
Very Satisfied (≥4.5)	3
Satisfied (3.5–4.4)	17
Neutral (2.5–3.4)	10
Dissatisfied (<2.5)	0
Satisfaction Level	Frequency (n)

Participants gave the highest scores to:

- “The hands-on prototype session helped me understand the concept” (Avg. = 4.3)
- “The facilitators were helpful during the practical session” (Avg. = 4.2)

Lower average scores (but still acceptable) were recorded for “the duration and structure of the workshop were appropriate” (Avg. = 3.4)

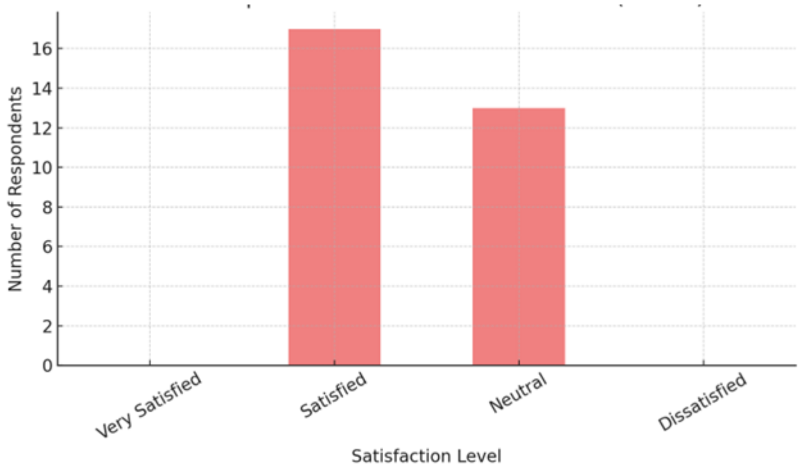

FIGURE 5. Workshop Satisfaction Level Distribution

As illustrated in Figure 5, the majority of participants (17 out of 30) reported being Satisfied with the overall workshop experience, while 13 students expressed a Neutral response. Notably, no participants indicated being Very Satisfied or Dissatisfied, suggesting that while the workshop effectively met expectations, there remains potential for enhancing the learning experience to achieve higher levels of satisfaction. This feedback aligns with observations from the satisfaction survey, where students appreciated the hands-on prototyping sessions and mentorship but identified time constraints and content depth as areas for improvement.

These findings echo the importance of practical, mentor-led learning in improving engagement and knowledge retention (Ain et al., 2021; Auflem, 2023). However, time constraints limited deeper exploration into some of the topics, suggesting a need for more structured follow-up or multi-day training in future iterations.

DISCUSSION

The findings of this study affirm the effectiveness of integrating microcontroller-based prototyping into community education as a means to improve health technology awareness among vocational students. By bridging theoretical exposure and hands-on experimentation, the workshop successfully elevated participants’ understanding of the relevance, function, and future potential of health technologies in real-world applications. These outcomes are consistent with global efforts to address digital health literacy gaps, particularly in underserved, rural, or resource-constrained settings

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(Manyazewal et al., 2021). In line with the study by Jahan et al. (2020), which demonstrated the utility of mobile health interventions in rural Bangladesh, our results show that students in similar socioeconomic contexts respond positively when exposed to structured, interactive learning experiences that are relevant to their local needs and future career prospects.

The university-school collaboration model used in this workshop not only fostered upward knowledge transfer to vocational students but also enabled downward mentoring from senior university students—providing a dual benefit. This experiential interaction strengthens both pedagogical and soft skills for university students while simultaneously empowering vocational participants. Such models exemplify the tridharma philosophy in Indonesian higher education, which emphasizes the integration of education, research, and community service.

Comparatively, Ain, Rulaningtyas, and Putra (2021) conducted a similar workshop for SMK students focusing on audiovisual-based fatigue detection devices. Like our study, theirs noted an increase in enthusiasm and perceived relevance of medical technology, although it lacked a structured awareness measurement tool. Our incorporation of the Health Technology Awareness Index (HTAI) offers a clear advancement by providing a quantitative baseline and post-intervention evaluation. This addresses a notable gap in previous educational intervention literature, where anecdotal or qualitative feedback often substitutes for measurable outcomes (Mukherjee et al., 2024; Ehteshami et al., 2013).

Additionally, the inclusion of a participant satisfaction instrument enabled the evaluation of instructional quality, module effectiveness, and learner engagement. The finding that participants rated hands-on sessions and mentor support highly is aligned with the conclusions of Tam et al. (2017), who demonstrated the critical role of interactive formats in changing learner attitudes and reducing perceived stigma toward technology use.

However, several limitations should be acknowledged. The workshop was conducted over a single day, limiting the depth of technical exploration. While the session succeeded in stimulating interest, time constraints may have restricted students from fully internalizing advanced concepts such as device calibration, signal conditioning, or user-centered design processes, which are key in professional biomedical engineering practice (Rodriguez et al., 2023).

Another area of future improvement is the inclusion of gender-sensitive and accessibility-oriented perspectives in health technology education. As noted by Griewing et al. (2024), awareness and intention to use digital health technologies can vary significantly across demographic groups, and educational programs must be inclusive by design.

Moreover, the prototyping activity focused primarily on hardware-based solutions. Future iterations could incorporate software and IoT components, such as cloud-based data visualization or Bluetooth-based health data sharing—skills that are becoming increasingly essential in modern health informatics (Ezeudoka et al., 2024; Pai & Alathur, 2019).

To enhance the effectiveness and sustainability of such programs, we recommend the following longitudinal Monitoring by introduce a follow-up phase 3–6 months post-workshop to assess retention and potential application of skills learned, perhaps via mini projects or competitions. Multi-Day Modular Workshops also one of the recommended actions that can expand the intervention into a series of workshops to deepen learning on microcontroller programming, safety regulations, and device usability testing. Cross-Disciplinary Involvement also can be conducted which integrate nursing, pharmacy, or informatics students in the facilitation team to model real-world interdisciplinary collaboration in health technology development. Moreover, digital integration needs to be provided by developing a companion digital platform or mobile app to reinforce concepts post-workshop and allow for community-driven

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prototype sharing and discussion. However, HTAI Instrument must be validated to continue refining the HTAI tool across different populations and settings to establish its reliability and generalizability as a standard evaluation instrument.

CONCLUSION

This study demonstrated that a community-based workshop on medical equipment prototyping can effectively enhance health technology awareness among vocational students, especially those from rural areas with limited exposure to digital health systems. By integrating lectures, hands-on activities, and mentoring, the workshop enabled participants to engage directly with concepts and tools that are central to modern health care delivery. The pre- and post-test results using the Health Technology Awareness Index (HTAI) showed a significant increase in students' knowledge and perceived relevance of health technologies. Furthermore, participant satisfaction data revealed that students found the workshop engaging, relevant, and impactful, particularly in the areas of hands-on learning and support from facilitators. The findings support the broader literature advocating for early exposure to digital health technologies and underscore the role of participatory and prototype-driven education in promoting equity and innovation in health technology adoption.

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