

ORIGINAL RESEARCH ARTICLE

Empowering business students through culturally responsive Internet of Things education: insights from a modular biomedical circuit curriculum

Yu-Ming Fei, PhD^a and Wen-Chiang Liu, MEd^{b*}

^aGraduate Institute of Business Intelligence and Innovation, Chihlee University of Technology, Taipei, Taiwan; ^bDepartment of Business Administration, Chihlee University of Technology, Taipei, Taiwan

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This research investigates the design and application of a culturally appropriate, modular Internet of Things (IoT) learning module for undergraduate business students, responding to the demand for interdisciplinary education merging technology and business expertise. By blending modular biomedical circuits, IoT power management and a blended learning approach, this course sought to promote student engagement, technological confidence and relevant innovation. Students assembled biomedical sensor circuits, like heart-rate and temperature monitors, which connected to IoT dashboards for data visualisation, to experience tangible links between physical computing and business. The course included 128 students from two groups, ending with individual projects and team contests. Data for this qualitative study came from student journals, focus groups and project artefacts. Four major results were found by the thematic analysis: learner motivation increased via modular practice, comprehension improved through contextualised applications, interdisciplinary collaboration skills grew and competitive innovation outcomes benefited from successful knowledge transfer. Five student teams' projects earned national recognition; they involved smart poultry farming and energy-efficient hospitality systems. These findings emphasise how IoT education can enable non-Science, Technology, Engineering, and Mathematics (non-STEM) learners.

Keywords: IoT education; business students; biomedical circuits; qualitative research; responsive pedagogy; blended learning; innovation projects

Introduction

As industries speed up toward digital transformation and sustainable development, higher education institutions face mounting pressure to prepare students with both technological literacy and application-oriented competencies. This imperative extends beyond traditional STEM disciplines to encompass business and management education, where digital tools such as the Internet of Things (IoT) have become increasingly integral to sustainable innovation and organisational transformation (Sarmiento-Rojas et al., 2022; Zhou & Brown, 2020).

However, integrating IoT education into non-STEM curricula presents substantial pedagogical challenges. Business students often lack prior exposure to electronics,

*Corresponding author. Email: joule330@gmail.com

circuit design or embedded systems, resulting in lower confidence and engagement when confronted with technically complex content (Ramohalli & Adegbija, 2018). Conventional IoT education models emphasise hardware functionality and module-level instruction, overlooking real-world application contexts and learners' socio-cultural identities (Zhou & Brown, 2020).

Culturally responsive pedagogy offers an interesting framework for addressing this gap. Grounded in the recognition that student learning is shaped by cultural context, this approach emphasises relevance, inclusivity and identity-affirming instruction (Gay, 2002; Howard, 2001; Ladson-Billings, 1995). In STEM education, responsive teaching has been shown to increase motivation, self-efficacy and active participation amongst underrepresented learners (Cheng et al., 2021).

Blended learning and modular instructional design are increasingly employed to enhance accessibility and engagement in technical education. Blended formats allow for flexible integration of online simulation tools and in-person lab practice (Graham et al., 2005; Thorne, 2003), whilst modular electronics projects promote iterative learning and creative problem-solving (Ramohalli & Adegbija, 2018).

The intersection of these strategies – responsive teaching, blended learning and modular IoT project-based education – represents an under-explored yet promising direction for empowering non-STEM students to take part in technological innovation (Roschelle et al., 2000). When learners are provided with contextualised applications and opportunities for real-world problem-solving, they are more likely to internalise knowledge and engage with digital technologies.

This study examines an IoT learning module that was created and put into practice for a business technology course. This course will cover biomedical circuits, IoT power management and sustainability challenges. Students in this module built, tested and connected small biomedical sensor circuits, including heart-rate and infrared temperature sensors, to IoT dashboards for data collection and visualisation. This practical approach allowed business students, even without an engineering background, to explore hardware and software integration and understand IoT concepts in business fields like health monitoring and service innovation. With 128 students on 23 teams over 2 school years, the curriculum highlights hands-on study and collaborative design. Through the examination of student reflections, focus groups and innovation artefacts, this study furthers the conversation on interdisciplinary, technical education.

This research offers both theoretical and practical insights into how culturally contextualised IoT education can support business students in developing technical fluency, sustainable design thinking and community-responsive innovation skills.

To sum up, this research is driven by the need to connect tech advances with non-STEM learners, especially in business studies. This research aims to investigate how interdisciplinary methods can foster greater engagement and equip learners to meaningfully contribute to digital and sustainable futures, by teaching culturally relevant, practical skills to students without technical backgrounds. This research helps the field by showing a design-based method to teach IoT in business (not STEM), following the guidelines of culturally responsive teaching. By adapting theories into real-world application via flexible, blended and localised learning, it connects a key gap in current academic work. Figure 1 presents the conceptual framework guiding this study.

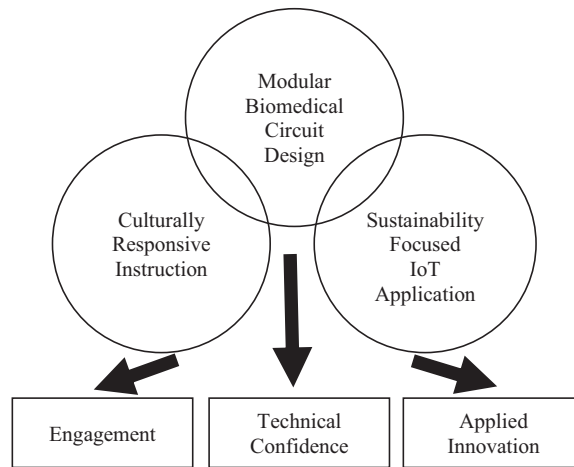


Figure 1. Conceptual framework of the curriculum. IoT: Internet of Things.

Literature review

Biomedical circuit education in higher education

Biomedical electronics have emerged as a critical component of interdisciplinary learning, particularly in health and technology-related fields. Integrating biomedical circuit design into undergraduate curricula can enhance students' understanding of practical healthcare technologies whilst fostering cross-domain problem-solving skills. Institutions such as the University of North Dakota have introduced specialised programs like the Biomedical IoT Devices certificate, blending engineering, IoT and healthcare for experiential learning (University of North Dakota, n.d.).

Integration of sustainability principles in IoT education

Sustainability has become a foundational value in education for the 21st century, particularly in courses involving technological innovation. Embedding sustainability principles into IoT education enables students to connect environmental awareness with system design and application. For example, the University of Tasmania has been globally recognised for its curriculum's emphasis on climate action and sustainable impact (University of Tasmania, 2023). Sarmiento-Rojas et al. (2022) advocate for curriculum designs that include real-world sustainability challenges to inspire ethical innovation amongst students.

Applications of IoT in higher education

IoT has gained significant traction in higher education for its role in enhancing both institutional efficiency and student engagement. Studies highlight its utility in smart campus initiatives, asset tracking and classroom interactivity (Zhou & Brown, 2020). Practical IoT applications are increasingly used in engineering and design-based education, allowing students to engage with live data and networked devices to create meaningful solutions (Roschelle et al., 2000).

Transforming student interest through hands-on IoT projects

Hands-on IoT projects are highly effective in increasing learner motivation and translating theoretical knowledge into applied skills. By engaging with modular electronics and interactive tasks, students develop a deeper sense of ownership and confidence in their learning process. Zhou and Brown (2020) emphasise that non-STEM learners, when given the opportunity to work on real-world IoT scenarios, show improved engagement and interdisciplinary curiosity. Graham et al. (2005) and Thorne (2003) further support the role of blended and project-based learning in enhancing student autonomy and technological fluency.

Culturally responsive teaching also intersects meaningfully with project-based IoT education. The work of Gay (2002), Gay (2018), Ladson-Billings (1995) and Howard (2001) illustrates how affirming students' identities and community experiences can increase motivation and learning outcomes, particularly in technical disciplines. Cheng et al. (2021) found that culturally responsive teaching methods within sustainability-focused marine education settings improved student involvement and knowledge retention.

These strands of research collectively support the pedagogical approach of this study: integrating biomedical circuits and IoT through culturally responsive, sustainability-driven and hands-on learning experiences to promote student engagement, innovation and cross-disciplinary relevance.

Research gap and contribution of this study

Whilst existing literature provides strong support for integrating sustainability, culturally responsive pedagogy and hands-on IoT education, most studies focus either on STEM contexts or general technological adoption. Few have examined how these principles can be effectively applied in non-STEM environments – especially in business education, where students typically lack foundational technical training.

Although biomedical circuit education and IoT practices are emerging in engineering programs, their adaptation to business curricula, with attention to learned diversity and practical application, remains under-explored. Previous research has emphasised either theoretical modelling or institutional deployment of IoT tools, often neglecting learner-centred design and personal engagement in the innovation processes.

This study addresses these gaps by implementing a modular, culturally responsive IoT curriculum specifically designed for business undergraduates. Through integrating biomedical circuits and sustainability-focused applications, this research contributes to a novel interdisciplinary framework that enhances student engagement, innovation capability and cultural relevance in technical education for non-engineering learners.

Methods

Research context and participants

The research was conducted over 2 academic years (2023 and 2024) at a comprehensive university in Taiwan, within a required IoT learning module integrated into a digital technology course for 3rd-year undergraduate students in the College of Business and Management. A total of 128 students took part across two cohorts.

Students were divided into 23 teams, each comprising 5–6 members, and engaged in both individual and collaborative components of the curriculum.

Amongst the 128 participants, 85 were female (66.4%) and 43 were male (33.6%). Whilst most students came from various programs within the College of Business and Management, a subset of 16 students (12.5%) were identified as majoring in Information Management based on their departmental affiliation.

All students had minimal or no prior experience with electronic circuits or IoT systems, intervening relevant for assessing cross-disciplinary learning outcomes in non-STEM contexts. The diversity in student backgrounds, especially in terms of technical familiarity and program affiliation, provided a rich basis for exploring how culturally responsive and hands-on curricula influence engagement and learning.

Course design and pedagogical approach

To support hands-on exploration and application-based learning, the course employed a curated set of IoT development tools and sensors. The primary development board was the Wemos D1 R32, an ESP32-based microcontroller equipped with both Bluetooth and Wi-Fi communication capabilities. This board provided students with an accessible platform for coding, prototyping and wireless data transmission.

For the biomedical circuit practice, students used an infrared heart rate sensor and a contact-type temperature sensor, which allowed them to engage with real-world physiological data and understand basic bio-signal processing.

In the smart living and environmental sensing modules, components included the Digital Humidity and Temperature (DHT11) sensor, Radio-Frequency Identification (RFID) readers, and photoresistors for light detection. These modules supported application scenarios, such as home environment monitoring, access control systems and light-responsive automation.

The power management unit featured Allegro Current Sensor (ACS712) modules, which allowed students to measure, record, and analyse real-time energy consumption data. All data collected from sensors were transmitted and visualised through the Blynk IoT platform, which facilitated real-time mobile monitoring and remote device control. This platform enabled students to experience cloud-based IoT interaction without complex setup requirements. The course was structured around three interconnected instructional modules. Figure 2 presents the modular IoT curriculum design applied in this study:

- **Modular Biomedical Circuit Practice:** Students used pre-configured components to build and test basic biomedical circuits, such as heart rate sensors, through guided lab activities. This phase focused on familiarising students with electronics in a low-barrier, exploratory format.
- **IoT-Based Power Management Integration:** Building on their individual experiences, students were introduced to IoT development boards and sensors to design simple systems for monitoring and optimising power consumption. These systems were linked to sustainability issues and local community scenarios.
- **Group Innovation Project and Competition:** Students formed teams to develop applied IoT prototypes addressing real-world challenges, particularly in the domains of sustainable living, community health and digital management.

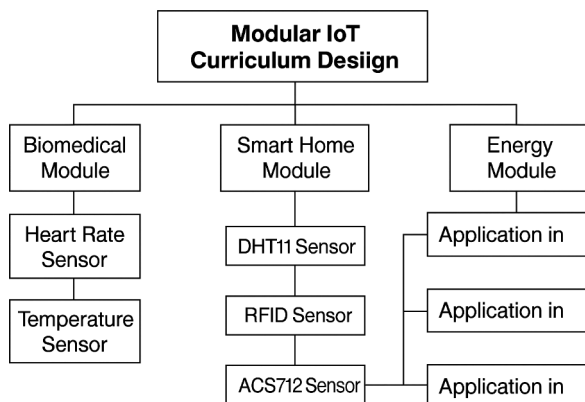


Figure 2. Modular IoT curriculum design. IoT: Internet of Things.

Final projects were submitted to internal showcases and external innovation competitions, with five teams earning national awards.

The pedagogy emphasised cultural relevance, iterative design and learned autonomy. Discussions on how technology intersects with students' everyday lives and communities were embedded throughout the course to promote contextual understanding and intrinsic motivation.

Data collection methods

Multiple qualitative data sources were used to triangulate findings and deepen insights into students' learning experiences:

- **Weekly Reflection Journals:** Students submitted short weekly reflections documenting their thoughts, challenges and insights related to course activities. These reflections offered rich longitudinal data on developing perceptions and learning strategies.
- **Focus Group Interviews:** At the end of the semester, semi-structured group interviews were conducted with a subset of students from each cohort. These discussions explored themes, such as cultural relevance, self-efficacy and collaborative innovation.
- **Project Artefacts:** Final project reports, presentation slides, design sketches and competition entries were collected and analysed to understand how students translated their learning into applied outcomes.

Data analysis

All qualitative data were coded and analysed thematically, following the approach of Braun and Clarke (2006). The process involved:

- Familiarisation with the data
- Generating initial codes across the dataset

- Identifying and reviewing themes related to motivation, engagement, cultural connection and innovation
- Defining and naming themes
- Synthesising findings with illustrative quotes and examples

Themes were cross-validated across data types to ensure credibility and consistency. Reflexivity was maintained through ongoing researcher memos and peer debriefing.

Ethical considerations

All participants provided informed consent prior to participation. Pseudonyms were used in reporting qualitative excerpts to protect student anonymity. This study was approved by the university's institutional review board and conducted under ethical research standards in educational settings.

Data triangulation and trustworthiness

To ensure methodological transparency and enhance the trustworthiness of the findings, this study employed a multi-source triangulation strategy. The primary qualitative data consisted of students' reflective journals and their final project outcomes, which served as the core materials for thematic coding and interpretation. Each student was assigned an anonymised identification code derived from their enrolment number to maintain confidentiality and data consistency throughout the analysis.

Although the qualitative coding was initially performed by the course instructor, the final project evaluations were independently reviewed by three faculty members with expertise in IoT and instructional design. The averaged scores of these reviewers were used to strengthen the reliability and impartiality of the assessment process.

In addition to these primary data sources, institutional course-evaluation records were consulted as secondary validation evidence. Whilst student satisfaction was not a direct research variable, the course received ratings substantially higher than the university's overall average, suggesting that learners perceived the culturally responsive and hands-on IoT module positively. This indirect indicator further supports the credibility of the qualitative findings by reflecting students' genuine engagement and appreciation of the instructional design.

Overall, the integration of reflective narratives, project artefacts and institutional evaluation data provided a coherent triangulation framework that reinforced the internal consistency and validity of the study's qualitative results.

Results

Enhanced engagement through modular practice

Students consistently reported heightened engagement and curiosity when interacting with hands-on biomedical circuits. The modular design, characterised by low cost and simplicity, allowed learners to experiment iteratively without fear of failure. This accessible entry point proved beneficial for students with limited prior exposure to

electronics, enabling them to build confidence through tangible outcomes. The ability to test, adjust and observe immediate feedback from sensors reinforced learning motivation and fostered a mindset of technical exploration. These findings align with constructivist principles, suggesting that modular practice not only facilitates content acquisition but also cultivates learned agency in technology-enhanced environments.

Cultural relevance and application thinking

Integrating IoT assignments with culturally relevant themes – such as community health monitoring, energy conservation and local environmental concerns – significantly enhanced students' ability to contextualise their technical learning. Reflection data revealed that such framing bridged the abstract logic of sensors and circuits with students' lived experiences and social identities. For instance, students referenced family scenarios or local challenges when describing their project inspirations, showing that cultural grounding played a key role in knowledge internalisation. This outcome supports the theoretical premise of culturally responsive pedagogy, which emphasises relevance as a driver of deeper cognitive engagement and sustained application thinking.

Collaborative innovation and achievement

All 23 student teams successfully proposed original IoT projects addressing real-world challenges, with a subset demonstrating notable success in competitive innovation contexts. Five teams advanced to national-level competitions: two received top awards for developing smart poultry farming systems, one secured second prize for a smart hospitality solution and two earned honourable mentions for IoT-based energy management tools. These achievements reflect not only the feasibility of interdisciplinary project-based learning but also the curriculum's effectiveness in translating technical content into actionable innovation. The ability of business students to compete – and succeed – alongside traditional STEM learners underscores the potential for inclusive, hands-on IoT education in fostering entrepreneurial and solution-oriented thinking.

Perceived outcomes and personal growth

Students' reflective accounts indicated substantial personal and academic development resulting from their engagement with the curriculum. Common themes included increased self-efficacy in technical problem solving, heightened interest in interdisciplinary collaboration and a stronger orientation toward using technology for social and environmental good. Several students identified new career aspirations in digital innovation or sustainability-related fields, crediting the course by expanding their perceived professional trajectories. Teaching the IoT in a way that connects with people's lives helps them learn technology and also grow as individuals, preparing them to make a difference.

Thematic analysis of student reflections

To further understand students' learning experiences beyond performance scores, a thematic analysis was conducted on 34 individual reflection entries. Following the Braun and Clarke's (2006) method, four major themes emerged, which highlight

students’ developing perceptions, motivations and identity shifts during the course: Technical Confidence, Socially Relevant Inspiration, Innovation Readiness and Peer Influence and Collaboration.

As presented in Table 1, many students reflected on overcoming initial anxieties related to electronics, emphasising their surprise and satisfaction at achieving hands-on functionality. Others connected their project ideas to family or community needs, suggesting that culturally grounded learning contexts enhanced relevance and motivation. Students also noted a growing sense of innovation capability, reporting increased comfort by proposing novel solutions using IoT technologies. Importantly, peer dynamics – both formal teamwork and informal support through social platforms – played a central role in maintaining momentum and morale throughout the semester. These themes suggest that when the technical content is framed in meaningful contexts and paired with accessible, modular instruction, non-STEM learners can develop not only technical competence but also a sense of agency, creativity and belonging in digital innovation spaces. The thematic insights complement the quantitative outcomes by revealing the internalised, affective dimensions of the learning process.

Quantitative learning outcomes

To supplement the qualitative themes, this study also analysed the quantitative learning outcomes of the 128 participating students. The assessment framework encompassed three learning dimensions: IoT conceptual understanding, circuit practice performance and innovation project application, evaluated, respectively, through mid-term written exams, hands-on laboratory scores and final group project presentations.

Descriptive statistics revealed a strong overall performance across all three areas. On average, students scored 79.3 in IoT conceptual understanding (SD = 3.2), 81.5

Table 1. Thematic analysis of student reflections.

Theme	Description	Illustrative quote	Frequency
1. Peer influence and collaboration	Team-based progress and motivation were fuelled by social dynamics and informal peer recognition, often shared via messaging apps.	‘Our team kept sending each other photos of the sensors working – those moments pushed us forward.’	74 out of 128
2. Technical confidence	Students gained confidence in using sensors, circuits and digital tools despite lacking prior experience in electronics.	‘I was surprised I could connect all those wires by myself – it’s not just for engineers.’	35 out of 128
3. Socially relevant inspiration	Project ideas were often drawn from students’ lived experiences and communities, making the technical content feel personally meaningful.	‘My project idea came from watching my grandparents manage medication. I wanted to help people like them.’	26 out of 128
4. Innovation readiness	Students reported feeling capable of proposing or prototyping original IoT solutions, often expressing pride in their creativity.	‘Even though we’re not tech majors, this course made me feel like a real innovator.’	67 out of 128

in circuit practice (SD = 2.9) and 89.2 in their innovation projects (SD = 3.1). These results reflect both the accessibility of modular IoT instruction and the curriculum’s success in fostering applied skills amongst non-STEM learners.

Table 2 presents the comparative learning performance of students who took part in external innovation competitions and those who did not. Results show that competition participants achieved higher mean scores across both the total learning performance index and the innovation project dimension, with lower standard deviations suggesting greater consistency. These outcomes reinforce the value of authentic, challenge-based learning environments.

Additionally, students who took part in external innovation competitions ($n = 112$) demonstrated higher total learning performance ($M = 261.5$, $SD = 7.0$) than those who did not ($n = 16$; $M = 249.9$, $SD = 4.9$), as shown in Table 3. Their innovation project scores were also elevated ($M = 89.9$ vs. 86.2). This difference supports the notion that engaging in real-world challenges further enhances learning outcomes.

These findings quantitatively validate the qualitative insights presented earlier. Specifically, the statistically higher performance amongst competition participants supports the view that culturally grounded, application-oriented learning experiences can significantly enhance both technical mastery and innovation capacity. The low standard deviations observed amongst participants further suggest a positive effect on learning consistency and equity. A reliability check of the composite score yielded a Cronbach’s alpha of 0.84, showing high internal consistency.

Discussion

As a course-level instructional creation study, this research demonstrates how culturally responsive pedagogy can be effectively adapted to IoT education for non-STEM learners. The discussion of findings is grounded in this framework, connecting the observed learning outcomes, technological confidence, engagement and innovation to the principles of culturally responsive and hands-on learning.

In comparison with recent IoT-enabled smart learning studies such as Mohanty et al. (2024), which primarily examined engagement patterns in general classroom or STEM-oriented settings, this study revealed distinct behavioural and motivational

Table 2. Learning performance by competition participation.

Learning dimension	Mean score (Competition)	SD (Competition)	Mean score (No competition)	SD (No competition)
Total score	261.46	6.97	249.88	4.87
Innovation project	89.88	2.82	86.19	2.29

Table 3. Comparative scores by competition participation.

Competition participation	Total score (Mean)	Total score (SD)	Total_N	Innovation score (Mean)	Innovation score (SD)	Innovation_N
No	249.88	4.87	16	86.19	2.29	16
Yes	261.46	6.97	112	89.88	2.82	112

responses amongst business students. Participants in this module demonstrated stronger sustained engagement and collaborative interaction when cultural relevance and real-world commercial applications were integrated into learning tasks. These findings extend previous research by showing that a culturally responsive and context-driven IoT learning design can effectively broaden student motivation and participation beyond conventional technical disciplines.

These data align with earlier studies, highlighting perceived safety and independence's importance in keeping students involved. According to Roberts and Rajah-Kanagasabai (2013), when students feel less exposed, like in anonymous forums, they may participate more, particularly when self-efficacy is low. Although our course didn't use anonymous platforms, the low-barrier modular practice still promoted a safe experimentation space. This aligns with Krüger-Ross et al. (2013), who said less pressure helps students focus on tasks over social concerns.

Reflection data revealed that students referenced their learning routines and coping strategies, often describing late-night troubleshooting, peer consulting via social messaging apps and voluntary re-testing of circuit outcomes. These behaviours signal transforms passive reception to active management of learning tasks – an indicator of increased self-regulation and self-efficacy. Students reported feeling 'less afraid to try new things' or 'more confident even when I didn't know the answer', showing that instructional design directly affected emotional readiness and persistence, as supported by Ciampa (2014) and Junco et al. (2011) on motivational triggers in mobile and social learning environments.

In line with Braun and Clarke's (2006) thematic analysis, student reflections were categorised into four emergent domains: (1) Technical Confidence, (2) Socially Relevant Inspiration, (3) Innovation Readiness and (4) Peer Influence. Illustrative student comments included:

- 'I was surprised I could connect all those wires by myself – it's not just for engineers'.
- 'My project idea came from watching my grandparents manage medication. I wanted to help people like them'.
- 'Even though we're not tech majors, this course made me feel like a real innovator'.
- 'Our team kept sending each other photos of the sensors working – those moments pushed us forward'.

These voices reveal not just affective gains but socio-cognitive positioning shifts, consistent with the engagement spectrum described by Cavanagh (2011) and Rothstein and Santana (2011).

Integrated model of learning outcomes

This model illustrates the pedagogical flow from culturally responsive IoT instruction through student engagement and development, culminating in observable learning outcomes, including technical confidence, applied innovation and competition success.

The integrated learning model, shown in Figure 3, highlights the pathway through which culturally responsive, hands-on IoT instruction facilitated engagement and led to meaningful learning outcomes. This progression – from instructional design

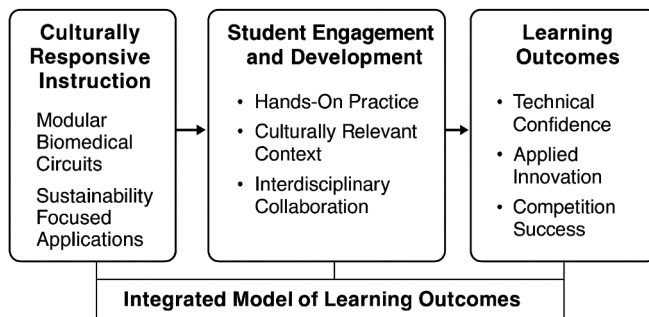


Figure 3. Integrated model of learning outcomes.

to student experience and eventual achievement – reflects the interplay of modular practice, cultural relevance and applied innovation emphasised throughout this study.

Theoretical implications and pedagogical contributions

Building on the pedagogical flow described in Figure 3, this section explores the theoretical and pedagogical implications of implementing culturally responsive IoT education in non-STEM higher education settings.

These findings also extend the theoretical scope of culturally responsive pedagogy by demonstrating its applicability within IoT-driven educational environments for non-STEM learners. Unlike prior implementations focused on language acquisition or K-12 STEM contexts, this model affirms its utility in interdisciplinary digital innovation for adult learners. Furthermore, this study contributes to the growing discourse on inclusive technology education by illustrating how modular, culturally situated instruction can empower learners from business-oriented disciplines to take part meaningfully in technologically mediated problem-solving.

This study supports the premise that culturally responsive, application-driven technical education can succeed in non-STEM domains. By using practical, modular tools and encouraging student creativity, the course bridged the gap between technology and business, theory and application, and individual learning and collective innovation.

The findings highlight the prizing contextual framing and student agency in curriculum design. When students perceive relevance and ownership, even highly technical content becomes accessible and meaningful.

The significant performance gap between competition participants and non-participants aligns with qualitative insights showing greater confidence, autonomy and engagement in real-world innovation amongst those actively involved in external challenges.

Conclusion and implications

Summary of findings

This study affirms the effectiveness of integrating culturally responsive pedagogy into modular IoT education to enhance the learning outcomes of non-STEM students. Through a curriculum centred on accessible biomedical circuit design and localised application contexts, students developed measurable competencies in three core areas: conceptual understanding, technical implementation and applied innovation.

Both qualitative and quantitative evidence show that learners experienced increased self-efficacy, motivation and interdisciplinary curiosity. These outcomes highlight the value of a pedagogical approach that bridges technological content with learners' personal and cultural identities.

Pedagogical implications

The course design presented in this study provides a transferable framework for promoting digital fluency in traditionally non-technical disciplines. By leveraging low-threshold modular tools and embedding them within community-relevant themes such as health, sustainability and social impact, educators can foster a deeper sense of ownership and meaning amongst students. This model challenges the assumption that innovation capacity is exclusive to STEM fields, demonstrating that hands on, context-driven instruction can transform business students into competent, creative agents of technological change. Institutions aiming to broaden participation in emerging technology fields should consider adopting interdisciplinary, culturally attuned curricula that encourages iterative learning, collaboration and responsible application.

Policy and institutional recommendations

To scale the benefits of culturally grounded IoT education, institutional commitment is essential. Universities and colleges should prioritise the development and integration of modular technology courses within non-STEM programs, particularly those serving diverse and underrepresented student populations. Faculty professional development is a critical enabler of this transition. Instructors from business, humanities or design backgrounds must be equipped with both technical fluency and pedagogical strategies to support identity-affirming instruction. Cross-disciplinary teaching initiatives, co-curricular project funding and collaborative curriculum design teams can further institutionalise such innovations. As digital transformation becomes a ubiquitous imperative across sectors, higher education systems must adopt inclusive, adaptable frameworks to prepare all learners – not just future engineers – for meaningful participation in the digital economy.

Beyond its pedagogical implications, this study contributes to the growing body of research on instructional design in technology-enhanced learning. By presenting a detailed case of a culturally responsive IoT learning module for business students, it offers empirical evidence and a replicable framework for integrating IoT-based experiential learning into business education.

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