Exploring Student Engagement and Learning Outcomes in an Intensive Interdisciplinary Course on Biomedical Device Innovation: A Pilot Study in Taiwan

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Abstract

This exploratory pilot study examined student engagement and learning outcomes in an intensive interdisciplinary summer course, *Biomedical Device Design and Development*. The original 18-week course was redesigned into a four-week modular program consisting of medical device regulations and risk management, artificial intelligence applications, biomedical sensor and microcontroller practice, and a Biodesign project emphasizing clinical needs. Thirteen students from diverse academic backgrounds at a research-oriented university in northern Taiwan participated. A convergent mixed-methods design was employed, integrating Likert-scale course evaluations (Cronbach's α = .89) with weekly learning reflections analyzed using thematic analysis. Quantitative results indicated that overall satisfaction increased across the four weeks (Week 1: M = 4.56; Week 4: M = 4.92). The biomedical sensor practice (M = 4.30) and Biodesign project (M = 4.15) received the highest ratings. Qualitative findings showed that hands-on and project-based modules promoted strong cognitive and emotional engagement and supported interdisciplinary knowledge integration. In contrast, the regulations module (M = 3.85) posed challenges due to abstract content and varied prior knowledge. Although limited by the small sample size (n = 13), the findings provide preliminary evidence that intensive interdisciplinary programs can enhance engagement and interdisciplinary learning, while highlighting the importance of scaffolding, module integration, and practice-oriented design.

Keywords: interdisciplinary education, student engagement, learning outcomes, intensive course, curriculum innovation

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Introduction

Background

In recent years, significant advancements in medical technology—especially in the domains of artificial intelligence (AI), biosensing technologies, and intelligent medical devices—have catalyzed the convergence of medicine and engineering, emerging as a prominent global trend within both educational and industrial sectors (Topol, 2019). The educational focus on biomedical innovation extends beyond the mere transmission of technical knowledge; it seeks to develop students' capacities to synthesize clinical requirements, engineering methodologies, and practical contexts, thereby enhancing interdisciplinary creativity and problem-solving competencies (Zenios et al., 2010).

Conventional semester-based courses, which typically span 16 to 18 weeks, frequently lead to fragmented learning experiences due to prolonged intervals between instructional sessions (Kember, 2004). Conversely, intensive course formats provide concentrated learning environments that facilitate deeper immersion, sustained engagement, and more effective integration of knowledge (Scott, 2003). Consequently, intensive courses are increasingly favored, particularly within interdisciplinary and practice-oriented educational programs.

Research Motivation and Problems

Interdisciplinary courses necessitate that students engage with multiple disciplinary languages, conceptual frameworks, and methodologies, resulting in heightened cognitive demands relative to single-discipline instruction (Newell, 2001). Within the context of biomedical device education, learners are required to concurrently comprehend regulatory frameworks, engineering technologies, clinical requirements, and innovation processes. This multifaceted integration poses considerable challenges, particularly for students with heterogeneous academic backgrounds (Klein, 2010).

Although there is an increasing interest in interdisciplinary education, empirical investigations focusing on intensive interdisciplinary courses in biomedical innovation remain scarce. Prior research predominantly addresses engineering or clinical education in isolation, rather than exploring integrated curricula that encompass regulatory aspects, artificial intelligence, sensor technologies, and Biodesign within a unified course structure.

Course Context

The course examined in this study, *Biomedical Device Design and Development*, was redesigned from an 18-week semester course into a four-week intensive summer program. The curriculum was organized into four modules:

1. Regulations and risk management
2. AI applications in healthcare
3. Biomedical sensors and microcontrollers
4. Biodesign innovation project

The course aimed to develop students' abilities in integrating technology, clinical needs, and innovation practices, aligning with the global Biodesign education model (Yock et al., 2015).

Research Purposes

This study aims to: (1) examine students' overall learning experiences in an intensive interdisciplinary course; (2) compare learning experiences across different modules; (3) identify learning challenges and support needs; and (4) integrate quantitative and qualitative findings to inform course design improvements.

Research Questions

1. What are students' overall learning experiences and engagement levels?
2. Are there differences in learning outcomes across modules?
3. What challenges do students encounter?
4. How do qualitative reflections explain quantitative results?

Literature Review

Interdisciplinary Education in Higher Education

Interdisciplinary education emphasizes the integration of knowledge, skills, and perspectives from multiple disciplines, enabling learners to understand and solve complex problems from diverse viewpoints. This approach has gained increasing attention in recent years, particularly in response to the rapid convergence of healthcare, engineering, and information technology (Holley, 2017). Klein (2010) noted that interdisciplinary education not only promotes innovative thinking and knowledge transfer, but also enhances students' problem-solving abilities in authentic contexts. Related studies further indicate that interdisciplinary collaboration fosters critical thinking, creativity, and teamwork skills among students (Borrego & Newswander, 2010).

However, interdisciplinary courses often face practical challenges, including large differences in students' academic backgrounds, variations in disciplinary language, and difficulties in integrating knowledge structures (Mansilla & Duraisingh, 2007). These challenges are particularly pronounced in biomedical device, medical engineering, or technological innovation programs, where students must simultaneously understand clinical needs, engineering design, regulatory requirements, and clinical workflows. As a result, interdisciplinary learning may impose a higher cognitive load on students. Therefore, providing appropriate scaffolding, supporting knowledge bridging, and facilitating collaborative processes are critical issues in interdisciplinary course design.

Student Engagement and Learning Outcomes

Student engagement is a central concept in learning research and is widely regarded as a key predictor of learning outcomes and motivation (Trowler, 2010). Fredricks et al. (2004) categorized student engagement into three dimensions: (1) behavioral engagement—participation in class activities, task completion, and effort investment; (2) emotional engagement—interest, enjoyment, and affective connection; and (3) cognitive engagement—deep thinking, strategy use, and knowledge construction.

A substantial body of research suggests that higher levels of student engagement are associated with deeper understanding, increased learning motivation, and improved knowledge transfer (Kahu & Nelson, 2018). In interdisciplinary courses, student engagement is particularly important, as such courses often involve complex content that requires higher levels of cognitive and emotional investment (Luo et al., 2020). Moreover, practice-oriented or problem-based learning approaches are known to enhance engagement. In engineering and healthcare technology education, hands-on activities, clinical cases, and project-based tasks have been shown to promote authentic learning engagement (Prince, 2004).

Intensive and Modular Programs

Intensive courses have gained prominence as a preferred instructional approach, distinguished by the delivery of concentrated learning within a condensed timeframe to facilitate immersive educational experiences. According to Scott (2003), such courses contribute to maintaining students' attention, fostering the integration of knowledge, and enhancing the overall focus of the curriculum. This instructional format is particularly well-suited to disciplines that demand practical application, technical skill development, or project-based learning, such as engineering, healthcare, and technology-related fields. Nonetheless, the accelerated nature of intensive courses can introduce challenges, including heightened course-related stress and increased cognitive load (Hyun et al., 2006). Moreover, in the absence of effective integrative activities, the learning process may become disjointed.

Modular course design segments complex interdisciplinary subject matter into thematic units, thereby enabling students to progressively build their understanding (Lockyer et al., 2017). However, in the absence of explicit linkages between these modules, learners may encounter difficulties in comprehending the overarching framework, which can lead to the acquisition of fragmented rather than cohesive knowledge (Brunton et al., 2018). Within the context of biomedical device innovation education, topics such as regulatory frameworks, artificial intelligence technologies, sensor design, and clinical needs assessment vary considerably in terms of learning pace, levels of abstraction, and requisite skill sets. Consequently, the integration of modules emerges as a pivotal element in the design of effective curricula.

Biomedical Device Innovation Education

Biomedical device innovation education emphasizes the integration of clinical needs, engineering design, and regulatory management. The Biodesign model, developed at Stanford University, proposes using clinical needs as the starting point for innovation. Through the Identify–Invent–Implement process, students are guided to conceptualize and design feasible medical technologies within authentic clinical contexts (Yock et al., 2015). This model integrates medicine, engineering, management, and regulatory considerations, making it a representative example of interdisciplinary education.

Hands-on learning with sensors and microcontrollers plays an important role in biomedical device education. Practical experience with physiological signal sensing—such as ECG, pulse oximetry, and pressure sensing—can enhance students' understanding of biological mechanisms, electronic circuits, and data processing, while also improving engineering practice skills. In addition, medical device design must comply with regulatory requirements and risk assessment procedures. Integrating regulatory education into the curriculum helps students understand commercialization feasibility and product lifecycle management (Shah et al., 2019). Overall, biomedical device innovation education is inherently interdisciplinary, encompassing technical, clinical, regulatory, and entrepreneurial competencies, which aligns closely with the course examined in this study.

Research Gap

A review of existing studies indicates that interdisciplinary education, student engagement, and intensive courses have each been discussed independently in higher education research. However, the intersection of these three areas remains underexplored in the following respects:

1. Limited research on interdisciplinary biomedical device innovation courses: Previous studies primarily focus on engineering or medical education separately, with few examining comprehensive course models integrating regulations, AI, sensors, and clinical needs.
2. Insufficient research on intensive summer programs in technology and medical innovation education: Existing studies on intensive courses are largely concentrated in management, language learning, or general education contexts.
3. Lack of mixed-methods studies integrating student engagement, learning reflection, and module comparison: This gap is particularly salient in small-class interdisciplinary courses with diverse student backgrounds, where mixed-methods approaches are needed to analyze engagement levels and sources of learning difficulty across modules (Kahu & Nelson, 2018).

Accordingly, the present study seeks to address these identified gaps through the utilization of a mixed-methods approach to examine students' engagement and learning experiences within an intensive interdisciplinary biomedical device course. Furthermore, the study aims to offer recommendations for course enhancement. This investigation is explicitly framed as a pilot exploratory study, with the primary objective of delivering a comprehensive contextual analysis rather than generating widely generalizable findings, thereby laying the groundwork for subsequent large-scale research endeavors.

Methodology

Research Design

This study adopted a convergent mixed-methods design, in which quantitative and qualitative data were collected concurrently and integrated during the analysis stage to provide a more comprehensive understanding of students' learning processes (Creswell & Plano Clark, 2018). Quantitative data were primarily derived from a five-point Likert-scale course evaluation questionnaire used to capture students' evaluations of different aspects of the course. Qualitative data were drawn from students' weekly learning reflections, which complemented the quantitative findings by revealing deeper learning experiences, difficulties, and suggestions that could not be fully captured through questionnaire responses alone.

The purposes of adopting a mixed-methods design were threefold: (1) to identify the overall tendencies of the entire student group through quantitative data; (2) to gain an in-depth understanding of the challenges and contextual features of interdisciplinary learning through qualitative data; and (3) to enhance the trustworthiness and validity of the findings through triangulation of multiple data sources. The data collection procedures were reviewed and approved by the institutional ethics committee. All students participated anonymously and signed informed consent forms prior to participation.

Research Setting and Course Structure

The course investigated was an intensive summer interdisciplinary course titled *Biomedical Device Design and Development*, offered at a research university in northern Taiwan. It was organized in a modular format consisting of four major modules:

1. Regulations and Risk Management: This module covered the regulatory frameworks of the TFDA and FDA, medical device classification, risk management procedures (ISO 14971), and product life-cycle evaluation. Instruction mainly involved lectures, case analysis, and risk assessment practice.
2. AI Applications in Healthcare: This module introduced fundamental concepts of machine learning, examples of medical image interpretation, and applications of large language models in healthcare. Learning activities included demonstrations, data-processing exercises, and scenario-based discussions.
3. Biomedical Sensors and Microcontrollers: This module covered physiological signal sensing principles, the MAX30102 pulse oximeter sensor, the AD8232 ECG sensor, and ESP32 microcontroller programming. It emphasized hands-on practice, group collaboration, and interdisciplinary problem solving.
4. Biodesign Innovation Project: Based on the Stanford Biodesign needs-driven model, this module guided students through the Identify–Invent–Implement process. Student groups were required to develop conceptual solutions addressing real clinical needs.

The four modules were designed in a progressive sequence. The regulations module provided the industrial and institutional foundation; the AI and sensors modules offered technical competencies; and the project module integrated the preceding knowledge to support innovation design. This structure provided an appropriate context for examining interdisciplinary learning, module transition, and student engagement.

Participants

A total of 13 students participated in this study. All were voluntary enrollees and ranged from undergraduate to graduate levels. Participants came from diverse disciplinary backgrounds, including biomedical engineering, electrical engineering, nursing, physical therapy, rehabilitation science, clinical medicine, occupational therapy, education, and business administration (EMBA). The sample included 7 male and 6 female students.

The diversity of participants' backgrounds made the course an important context for observing interdisciplinary learning processes, learning gaps, and collaborative interactions. It should be noted that this study was a single-class pilot study, and the sample size (n = 13) is consistent with the scale commonly seen in exploratory case study research (Miles et al., 2014). However, it is insufficient for statistical inference or representative generalization. This limitation is further discussed in Section 7.

Research Instruments and Data Collection

Data collection involved two main instruments administered at the end of each week to ensure timeliness and completeness.

Five-Point Likert-Scale Course Evaluation Questionnaire

The researchers developed a course evaluation questionnaire using a five-point Likert scale (1 = strongly disagree, 5 = strongly agree) comprising three dimensions and eight items in total:

- Dimension 1: Student Engagement (2 items). Example: "I actively participated in discussions and hands-on activities during the course."
- Dimension 2: Learning Outcomes (3 items). Examples: "This course helped improve my understanding of biomedical sensing technologies." "I am able to apply what I learned in this course to real-world problem solving."
- Dimension 3: Course Structure and Organization (3 items). Examples: "The relationships among different modules were clear and easy to understand." "The course schedule was appropriate for learning."

The questionnaire was administered online via Google Forms after the final class session of each week, requiring approximately 5 to 10 minutes to complete. To ensure anonymity, no names or student identification numbers were collected. Two experts in biomedical education reviewed the questionnaire for content validity, and item wording was revised based on their feedback. A pilot test was conducted prior to formal implementation. The overall scale yielded a Cronbach's α of .89, with all subscale internal consistency coefficients above .80, indicating good reliability.

Weekly Learning Reflections

Qualitative data were derived from students' weekly learning reflections collected anonymously through Google Forms. A structured guiding framework required students to address four aspects: (1) What did I learn?; (2) What do I still find challenging?; (3) What feedback do I have for the instructor?; and (4) How did I engage with peers or hands-on activities?

Each reflection typically ranged from 150 to 400 words. Across the four weeks, a total of 49 reflections were collected (14 in Week 1, 12 in Week 2, 10 in Week 3, and 13 in Week 4). Responses were anonymized using codes such as S01_W1, representing the first student's reflection in Week 1.

Data Analysis

Quantitative Data Analysis

The quantitative data were analyzed using descriptive statistics, including the mean (M) and standard deviation (SD) for each item and dimension. Given the small sample size (n = 13), no inferential significance tests (e.g., t tests or ANOVA) were conducted. Instead, descriptive statistics were used to present overall trends and relative differences among modules, interpreted in conjunction with the qualitative findings. Analyses included: (1) week-by-week comparison of mean dimension scores; (2) module-level comparison of learning outcome items; and (3) examination of standard deviations to assess consistency of student ratings.

Qualitative Data Analysis: Thematic Analysis

The qualitative data were analyzed using the six-step thematic analysis approach proposed by Braun and Clarke (2006): (1) familiarization with the data; (2) open coding; (3) generating initial themes; (4) reviewing themes; (5) defining and naming themes; and (6) producing the report. Original quotations were used as supporting evidence to ensure transparency and traceability of interpretation.

To enhance reliability, intercoder checking was conducted. A second researcher independently coded approximately 30% of the reflections (about 15 entries), and the level of agreement reached 84% (Cohen's $\kappa \approx .81$), indicating good coding reliability. Any discrepancies were resolved through discussion until consensus was achieved.

Integration of Quantitative and Qualitative Data: Triangulation

Quantitative and qualitative data were integrated through triangulation using three strategies: (1) explanatory integration—qualitative themes were used to explain reasons behind quantitative differences; (2) convergent validation—convergent patterns across data sources strengthened conclusions; and (3) exploration of divergence—inconsistencies between data sources were revisited and interpreted rather than dismissed. This integrative approach enhances the interpretive depth of findings in complex learning contexts (Creswell & Plano Clark, 2018).

Results

Quantitative Results: Overall Course Evaluation Trends

Students' overall evaluations demonstrated a consistent upward trend over the course of the four weeks, with mean scores increasing from 4.56 (SD = 0.31) in Week 1 to 4.92 (SD = 0.15) in Week 4. The reduction in standard deviations over time indicates that students' assessments became increasingly uniform as the course advanced. Furthermore, all dimension scores surpassed the threshold of 4.0, indicating a generally favorable learning experience.

In Week 4, the course integration dimension attained the highest mean rating (M = 4.30), reflecting an enhanced student appreciation of the overall course structure following the completion of the Biodesign project. Items pertaining to instructor–student interaction consistently garnered elevated ratings (M ≈ 4.6–4.8), indicating that this aspect served as a significant positive influence throughout the duration of the course.

Regarding the comparison of individual modules, the Biomedical Sensors and Microcontrollers module (M = 4.30, SD = 0.34) and the Biodesign Project (M = 4.15, SD = 0.38) received the most favorable evaluations, suggesting that students particularly valued experiential learning and clinically focused, project-based activities. Conversely, the Regulations and Risk Management module obtained the lowest mean score (M = 3.85, SD = 0.52) and exhibited the greatest standard deviation, implying a wider range of student perceptions and indicating that this module posed more substantial learning challenges for certain participants.

Table 1
Module-Level Mean Scores and Standard Deviations for Learning Outcomes

Module	Mean (M)	SD
Regulations and Risk Management	3.85	0.52
AI Applications	4.05	0.41
Biomedical Sensor Practice	4.3	0.34
Biodesign Project	4.15	0.38

Qualitative Results: Thematic Analysis

The thematic analysis generated four core themes, each supported by representative student quotations.

Theme 1: Hands-On Learning Promoted Strong Cognitive and Emotional Engagement

Practical engagement with the sensor module—encompassing activities such as MicroPython programming and the wiring and calibration of the MAX30102 pulse oximeter—emerged as the most commonly reported positive learning experience. For instance, student S07_W2 remarked, "The moment I completed soldering and observed my heartbeat displayed on the screen, I truly comprehended the essence of biomedical engineering." Similarly, S03_W2 reflected, "Transitioning from unsuccessful wiring attempts to successfully detecting oxygen saturation was a frustrating yet significantly more meaningful experience than merely attending lectures." This theme corresponds closely with the dimensions of cognitive and emotional engagement as articulated by Fredricks et al. (2004).

Theme 2: The Regulations Module Created Learning Barriers Due to Abstract Content and Lack of Context

Several students lacking regulatory backgrounds, such as those in nursing, physical therapy, and education, indicated that the regulations module was excessively abstract and insufficiently linked to clinical practice. For instance, student S11_W1 remarked, "The TFDA classification system is complex. The explanation was clear, but I couldn't connect it to my clinical experience." Similarly, student S02_W1 proposed, "Using real medical device failure cases to explain regulations would make the content easier to understand." This qualitative theme aligns with the quantitative result showing that the regulations module received the lowest average rating (M = 3.85).

Theme 3: Expansion of Interdisciplinary Perspectives and Knowledge Integration

Throughout the progression of the course, especially during the Biodesign project, students demonstrated a growing awareness of the interrelationships among the various modules. For instance, student S05_W4 remarked, "When working on the need statement, I realized that the regulations, sensors, and AI we learned earlier were all helping us design better solutions." Similarly, student S09_W4 noted, "This course made me think for the first time about how my medical background can integrate with engineering and business, instead of being separate fields." These reflections underscore the integrative impact of the modular course design observed during the concluding phase.

Theme 4: Clear Demand for Instructional Support and Module Integration

Students proposed specific suggestions for course improvement in the following areas:

1. **Pre-course foundational support:** Some students lacked programming or electronics backgrounds and struggled initially. For example, S06_W2 noted, "Providing introductory MicroPython materials before class would reduce frustration."
2. **Explicit module connections:** Students suggested that instructors clarify how each week's content connects with other modules.
3. **More industry-based examples:** Students requested additional real-world Taiwanese biomedical industry cases, including failure cases.
4. **Increased discussion time:** Students expressed a desire for more opportunities for group discussion and interdisciplinary interaction.

Discussion

The results indicate that an intensive interdisciplinary summer course can effectively enhance students' interdisciplinary perspectives and learning motivation, particularly within modules that integrate theoretical frameworks with practical application. This outcome corroborates Scott's (2003) assertion that intensive courses facilitate immersive learning experiences, as well as Prince's (2004) emphasis on the role of practice-oriented instruction in fostering student engagement.

Nonetheless, several challenges emerged. The Regulations and Risk Management module exhibited the lowest mean score alongside the highest standard deviation (SD = 0.52), reflecting considerable variability in student perceptions. This variability suggests that students from diverse disciplinary backgrounds engaged with the module in markedly different ways, supporting Klein's (2010) contention that learners from distinct disciplinary cultures interpret shared content divergently. Additionally, insufficient interconnections among modules impeded students' ability to synthesize knowledge across topics, despite their comprehension of individual modules. This finding aligns with Brunton et al.'s (2018) characterization of modular learning structures as prone to "knowledge accumulation without genuine integration."

Qualitative data further revealed a pronounced student preference for case-based instruction and interactive discussions. The integration of industry-relevant examples and collaborative learning activities may enhance sustained motivation and facilitate the practical application of knowledge. The Biodesign project appeared to serve as a pivotal mechanism for knowledge integration during the course's final phase, indicating that project-based learning components should be expanded and potentially introduced earlier in future iterations of the course.

It is important to emphasize that the quantitative results represent descriptive trends rather than inferential statistics. Differences observed between module scores (e.g., Sensors module M = 4.30 versus Regulations module M = 3.85) should not be construed as statistically significant due to the limited sample size; rather, these findings should be regarded as exploratory and interpreted in conjunction with the qualitative data.

Conclusion

This pilot study provides several preliminary findings with implications for the design of future intensive interdisciplinary courses:

1. Intensive summer interdisciplinary courses can effectively enhance students' interdisciplinary perspectives and overall learning satisfaction, with satisfaction improving throughout the course (Week 1: $M = 4.56$ → Week 4: $M = 4.92$).
2. Modular course design supports knowledge construction, but explicit connections among modules are critical for promoting integrated learning outcomes.
3. Students face notable challenges related to foundational knowledge (e.g., programming and regulatory concepts) and abstract content, indicating the need for additional scaffolding.
4. Case-based instruction and group interaction are important strategies for maintaining student motivation and engagement.

Based on these findings, the following course design recommendations are proposed:

- Provide preparatory materials prior to the course (e.g., MicroPython introduction, overview of Taiwanese medical device regulations) to reduce differences in prior knowledge.
- Strengthen module connections through cross-module integration tasks, weekly bridging discussions, or explicit linking of technical knowledge within the Biodesign project.
- Introduce more real-world cases in the regulations module, including both successful and failed medical device examples, to contextualize abstract concepts.
- Design more structured group discussions and interdisciplinary collaboration activities to enhance behavioral and emotional engagement.

Limitations and Future Work

This study has several limitations that should be considered when interpreting the findings.

Small Sample Size and Lack of Statistical Inference

The principal limitation of this study is the limited sample size (n = 13), which precludes the application of inferential statistical methods such as ANOVA or correlation analyses. Consequently, all quantitative results should be regarded solely as descriptive, and it is not feasible to statistically assess differences across disciplinary backgrounds. To enable preliminary inferential analyses, future research should aim to increase the sample size to a minimum of 30 to 50 participants.

Single-Site Context and Limited External Validity

This investigation concentrated on a single course offered at a research university located in northern Taiwan. The course structure, instructional approach, and student demographics are highly specific to this particular context, thereby constraining the extent to which the findings can be generalized to other institutions or cultural settings. Subsequent studies could employ multi-site research designs to facilitate comparative analyses of courses across different universities or national contexts.

Cross-Sectional Design Without Long-Term Follow-Up

Data collection occurred throughout the duration of the four-week course; however, the study did not assess long-term learning outcomes, knowledge retention, or the persistence of interdisciplinary thinking. Subsequent research could incorporate follow-up assessments, such as surveys administered three months after course completion, or employ longitudinal methodologies to evaluate enduring effects.

Limitations of Self-Reported Data

Both the questionnaire responses and reflective accounts were self-reported, potentially introducing social desirability bias. To enhance the validity of future studies, it is recommended to integrate supplementary data sources, including classroom observations, performance evaluations (e.g., project grades), and interviews, in order to triangulate and corroborate the findings.

Potential Researcher Bias

The researchers' engagement in course-related activities may have introduced confirmation bias. While intercoder reliability was assessed, yielding an agreement rate of 84%, to address this concern, it is recommended that future research incorporate independent investigators in both data collection and analysis processes to improve objectivity.

Despite these limitations, this pilot study provides valuable exploratory insights and a detailed contextual description in an area with limited existing research. Future studies may expand sample sizes, conduct cross-institutional comparisons, incorporate control-group designs, and integrate additional learning outcome measures to further strengthen both theoretical and practical contributions to interdisciplinary course research.

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