

Navigating the adoption of research-based instructional strategies within the complex nature of higher education

Yessi Affriyenni^{1,*}, Helen Georgiou², and Noah Finkelstein³

¹*School of Physics, University of New South Wales, Kensington, New South Wales 2052, Australia*

²*School of Education, University of Wollongong, Wollongong, New South Wales 2522, Australia*

³*Department of Physics, University of Colorado Boulder, Boulder, Colorado 80309, USA*



(Received 11 March 2025; accepted 15 August 2025; published 9 September 2025)

Examining teaching practices in university physics is crucial for addressing the lack of student achievement in and engagement with the subject. Research-based instructional strategies (RBIS) offer evidence-based methods to enhance student engagement and learning outcomes, but face adoption challenges due to institutional, contextual, and individual barriers, particularly in higher-year courses. This case study investigates how second-year physics instructors at a research-intensive university within a trimester system engaged with RBIS, using the EPIC-implementation model to guide analysis. A case-study approach, using semistructured interviews and secondary data (e.g., course evaluations and materials), explored instructors' decision making through the EPIC-implementation model (exposure, persuasion, identification, commitment, and implementation). The study reveals how individual motivation, peer influence, institutional constraints, and discipline-specific challenges shape RBIS adoption. While some instructors maintained commitment, others reverted to traditional methods due to systemic barriers. Co-teaching dynamics played a key role in influencing adoption, yielding mixed results. The findings contribute to the growing literature on instructional change by highlighting the importance of institutional support, peer mentorship, and alignment with teaching philosophies in sustaining RBIS adoption in major courses beyond the first year. They highlight the need for supportive institutional frameworks, discipline-specific strategies, and the alignment of teaching methods with instructors' values. This study provides practical insights for educators, institutional leaders, and policymakers to encourage innovative teaching practices in higher education.

DOI: [10.1103/wvj-8y8k](https://doi.org/10.1103/wvj-8y8k)

I. INTRODUCTION

Improving the quality of teaching in higher education has become a priority, particularly in science, technology, engineering, and mathematics (STEM) disciplines such as physics, where traditional lecture-based approaches often fail to engage students effectively [1–3]. Research-based instructional strategies (RBIS) have emerged as powerful tools to enhance student engagement, critical thinking, and learning outcomes [4,5]. RBIS refers to a set of pedagogical methods that are grounded in empirical research emphasizing active learning, student-centered instruction, and frequent formative assessment. These approaches aim to

enhance conceptual understanding and problem-solving skills [4,6,7].

Common RBIS methods include Peer Instruction, Just-in-Time Teaching, small group problem-solving, and interactive techniques such as flipped classrooms and collaborative learning environments [8,9]. These strategies, which are grounded in evidence-based pedagogical research, have gained traction globally. Studies have shown that students in active learning environments outperform their peers in traditional lecture-based courses, demonstrating higher conceptual gains, increased retention rates, and improved attitudes toward learning [6,10]. Additionally, RBIS can help bridge equity gaps by providing more inclusive and interactive learning experiences, benefiting students from diverse backgrounds [11]. However, despite their proven benefits, the adoption and sustained implementation of RBIS remain inconsistent across higher education institutions, particularly in physics [12–16]. Challenges such as institutional barriers, discipline-specific constraints, and individual resistance often hinder broader adoption [12,17].

RBIS adoption is influenced by multiple factors, which can be categorized as systemic, contextual, and environmental. Systemic factors include institutional policies, workload

*Contact author: y.affriyenni@unsw.edu.au

[†]Also at Department of Science Education, Universitas Negeri Malang, East Java 65145, Indonesia.

Published by the American Physical Society under the terms of the [Creative Commons Attribution 4.0 International license](https://creativecommons.org/licenses/by/4.0/). Further distribution of this work must maintain attribution to the author(s) and the published article's title, journal citation, and DOI.

structures, and faculty incentives that shape instructional decisions [18–20]. Contextual factors refer to department-specific conditions, such as co-teaching dynamics and disciplinary expectations [16,21,22]. Meanwhile, environmental factors encompass broader external influences, including national education policies and global disruptions like the COVID-19 pandemic [23–25]. Understanding how these factors interact is crucial for analyzing RBIS implementation in higher education settings.

While most studies on RBIS adoption have centered on first-year physics courses [4,12,22,26–30], there is growing interest in how instructors engage with these strategies across a wider range of undergraduate settings, including second-year courses [31]. This study offers a case-study analysis of instructor engagement with RBIS, guided by the EPIC-implementation model [20]. Through this framework, we examine how instructors navigate adoption across varying motivational, institutional, and contextual conditions.

To explore these complexities, this study applies the EPIC-implementation [20] as a guiding framework. The EPIC-implementation model recognizes five stages: exposure, persuasion, identification, commitment, and implementation [20,32]. It was designed to guide the implementation of evidence-based practices and interventions across various public sectors, including education. It provides a comprehensive approach to understanding and facilitating the implementation process at multiple levels of influence, from individual practitioners to broader organizational and systemic factors [20].

The EPIC-implementation model primarily describes the multistage process of adopting teaching strategies. While systemic, contextual, and environmental influences interact with this process, they are not its central determinants. Instead, the model integrates various motivation, goal, and change theories to explain how instructors progress through adoption stages. By leveraging this framework, this study contributes to a deeper understanding of RBIS adoption within the structural, contextual, and environmental realities of higher education.

The paper is structured to comprehensively address the research question:

How and why did instructors navigate their choices regarding RBIS adoption?

II. METHODOLOGY

A. Research design

This study employed a case-study approach to explore the factors influencing the sustained implementation of RBIS within higher education at a research-intensive university. A case-study design was chosen for its ability to provide an in-depth, holistic understanding of complex phenomena within real-world settings [33].

Multiple data sources were used to ensure a comprehensive understanding of RBIS adoption. Semistructured

interviews formed the primary data source. Secondary data sources were collected from two course conveners covering all three second-year physics courses to enrich the analysis and provide context. These included student evaluations from the university’s course evaluation platform and a range of course materials such as lecture notes, lecture slides, tutorial questions, weekly problems, course outlines, and quiz responses. These materials informed the development of the interview protocol and were used to corroborate interview findings, ensuring a robust analysis.

The interview protocol was designed to capture instructors’ knowledge, perceptions, and decision-making processes regarding RBIS. Interview themes included how instructors learned about RBIS, the factors that influence their decisions, and their reflections on its implementation. A semistructured format provided the flexibility needed to adapt during interviews (see the Appendix) [34,35].

To ensure the validity of the instruments, feedback was sought from the supervisory team and external reviewers. Notably, the third author of this paper provided validation as an external reviewer, without involvement in the design or conduct of interviews. His contributions were based on his experience in physics education research.

B. Ethical considerations

Ethics approval for this study was obtained from the human research ethics committee of the university, and the study was categorized as low/negligible risk. Participants were briefed on the study’s aims and methods, and their participation was entirely voluntary, with the option to withdraw at any time.

Participants provided informed consent, and interviews were recorded and transcribed with their permission. To maintain anonymity and the careful handling of sensitive data, pseudonyms were used for the course names and instructors’ names.

C. Context

The research was conducted at a research-intensive university in Australia. In 2019, the university transitioned to a trimester system aimed at providing greater flexibility for students. The academic calendar features three regular terms and an optional summer term, as shown in Table I.

The school offers two physics majors: a bachelor of science with a major in physics and a bachelor of advanced science with a major in advanced physics. This study investigated the implementation of RBIS in all three second-year physics courses offered by the school. Two of these courses—*Quantum Physics* and the *Electromagnetism*—are mandatory for both programs, while *Classical Mechanics and Special Relativity* is only required for the Advanced Science program (see Table II). In 2023, the year of data collection, all courses were taught in a co-teaching format.

TABLE I. The trimester calendar.

Terms	Months
Term 1	February–May
Term 2	May–August
Term 3	September–December
Summer term	January–February

Co-teaching has been a long-standing practice in the department where this study took place, originally introduced during the semester system with 14 teaching weeks to distribute teaching responsibilities and reduce workload. Despite the transition to the trimester system, which condensed courses into a more intensive teaching period, the co-teaching structure was retained. Table II lists the instructors' names according to their allocated teaching periods, with the first half followed by the second half.

Each course is typically divided between two instructors, with one teaching the first half and the other taking over the second half. Week 5 often serves as a transition period, where instructors may coordinate their approaches to ensure continuity in course delivery. However, instructors generally have significant autonomy in designing the pedagogical methods for their respective halves, leading to variations in instructional strategies within the same course. Additionally, within each co-teaching arrangement, one instructor assumes the role of course convenor, responsible for overseeing course administration, while the other serves primarily as an instructor.

The *Quantum Physics* course introduces fundamental and advanced principles of quantum mechanics. It covers core topics such as wave functions, the Schrödinger equation, quantum measurement, entanglement, and quantum harmonic oscillators. Additionally, it explores applications in quantum information and periodic potentials.

The *Classical Mechanics and Special Relativity* course examines Newtonian mechanics through the Lagrangian and Hamiltonian formalisms. Key topics include variational principles, conservation laws, coupled oscillators, and normal modes. The course also introduces Einstein's special relativity, covering Lorentz transformations, four-vector formalism, relativistic kinematics and dynamics, and the relativistic Doppler effect.

The *Electromagnetism* course focuses on both theoretical and applied aspects of electric and magnetic fields using Maxwell's equations in both integral and differential forms. It includes topics on electromagnetic waves, boundary conditions, wave propagation, and applications in optics and modern physics.

D. Research methods

This study included all five physics instructors teaching second-year physics in the School of Physics, covering all three second-year courses offered. All instructors were invited to participate in an in-person interview via email or direct communication, and all agreed to participate. Interviews were conducted near the end of Term 1 or Term 2, 2023, depending on the course schedule, after teaching, with each session lasting approximately 60 min.

Although the five instructors were male, they varied in positions, career stages, and RBIS-based teaching knowledge and experiences. At the time of the interviews, the instructors' career stages ranged from senior lecturers to professors.

Most interviews were digitally recorded. Milo, however, did not consent to digital recording but agreed to have notes taken during the interview. As approved by the ethics committee, digital notes were taken during Milo's session. To ensure reliability, the second author of this paper also attended to assist with note-taking. At the end of this session, the notes from both members were compared for data verification.

Any discrepancies between the notes taken by the first author and the second author during Milo's interview were resolved through discussions. Follow-up queries were made to clarify minor details, with all instructors consenting to these inquiries. Three follow-up queries have been conducted. Milo and Henry1 were contacted for minor clarifications regarding specific course details and administrative changes during 2020–2022.

E. Data analysis

The study employed a qualitative method with a thematic analysis approach, allowing participants to describe their experiences in their own words [36,37]. As an exploratory study, thematic analysis was guided by the EPIC-implementation model to ensure alignment with its predefined

TABLE II. Courses and instructors' details.

Courses	Instructors' pseudonyms	Professional level (2023)	RBIS usage level
<i>Quantum Physics</i>	Henry1	Professor	High user
	Milo	Associate professor	Low user
<i>Classical Mechanics and Special Relativity</i>	Henry2	Professor	High user
	Maxi	Senior lecturer	Low user
<i>Electromagnetism</i>	Niraj	Associate professor	Nonuser
	Noris	Professor	Nonuser

stages. While the model provided a structured framework—exposure, persuasion, identification, commitment, and implementation—the analysis allowed for the emergence of subcategories and themes within these stages, ensuring a balance between structure and flexibility.

Exposure includes coding on how instructors were initially exposed to RBIS and the sources of this exposure. Persuasion includes coding on the factors that influence and hinder RBIS adoption. Identification includes coding on the compatibility of RBIS with instructors' personal values, beliefs, and teaching style. Commitment includes coding on the role of institutional and peer support in RBIS adoption, the instructors' decisions to use or not use RBIS, and their commitment to preparing for the implementation of RBIS. The full stages explanation of the EPIC-implementation model is shown in Fig. 2. Subcategories were classified as positive, negative, and neutral (for exposure only), with their proportions illustrated in Fig. 3, where the total number is indicated on the *x*-axis labels. A further breakdown based on emerging themes is presented in Figs. 4–7, highlighting the specific factors influencing instructors' engagement with RBIS.

Two software programs were used to analyze the data: QSR NVIVO 12 for early-stage coding, and MICROSOFT EXCEL for preliminary jotting and later-stage coding. Verbatim transcripts and digital notes were analyzed using thematic analysis. In general, the thematic analysis follows the phases shown in Fig. 1.

Familiarization with the data involved reading and reviewing the transcript, with significant excerpts highlighted for further analysis. Initial coding began with note-taking and manually organizing excerpts into MICROSOFT

EXCEL. Field notes and interview summaries helped refine the initial list of categories based on the EPIC-implementation model.

The thematic analysis in this study was guided by the EPIC-implementation model, focusing on the first four stages, while the implementation stage is examined in a separate paper. This decision was made due to the breadth and depth of data related to the implementation process, which warranted a dedicated analysis. The complexity of instructors' implementation practices also led us to integrate the TEval framework [38] within the Implementation stage to more effectively capture instructional dynamics and outcomes.

As the analysis progressed, emergent codes were categorized within the EPIC-implementation model to ensure findings were both rooted in participants' experiences and relevant to the broader literature. Examples of these emerging codes are provided in the second sentence of each stage description in Fig. 2. Subcodes developed within this process further captured nuances in instructional change, maintaining alignment with the model.

Thematic analysis began with summarizing coded data in relation to the research question and the EPIC-implementation model, ensuring insights were grounded in participant experiences. Themes were reviewed and refined through discussions with the second author, with collaborative input from the research team, and external groups were sought to strengthen the validity of the claims. An iterative process refined categories, omitting unused ones and creating new ones as needed, while final themes were carefully named to reflect the essence of the data.

Intercoder reliability was measured at this stage, involving the first and the second authors of this paper.

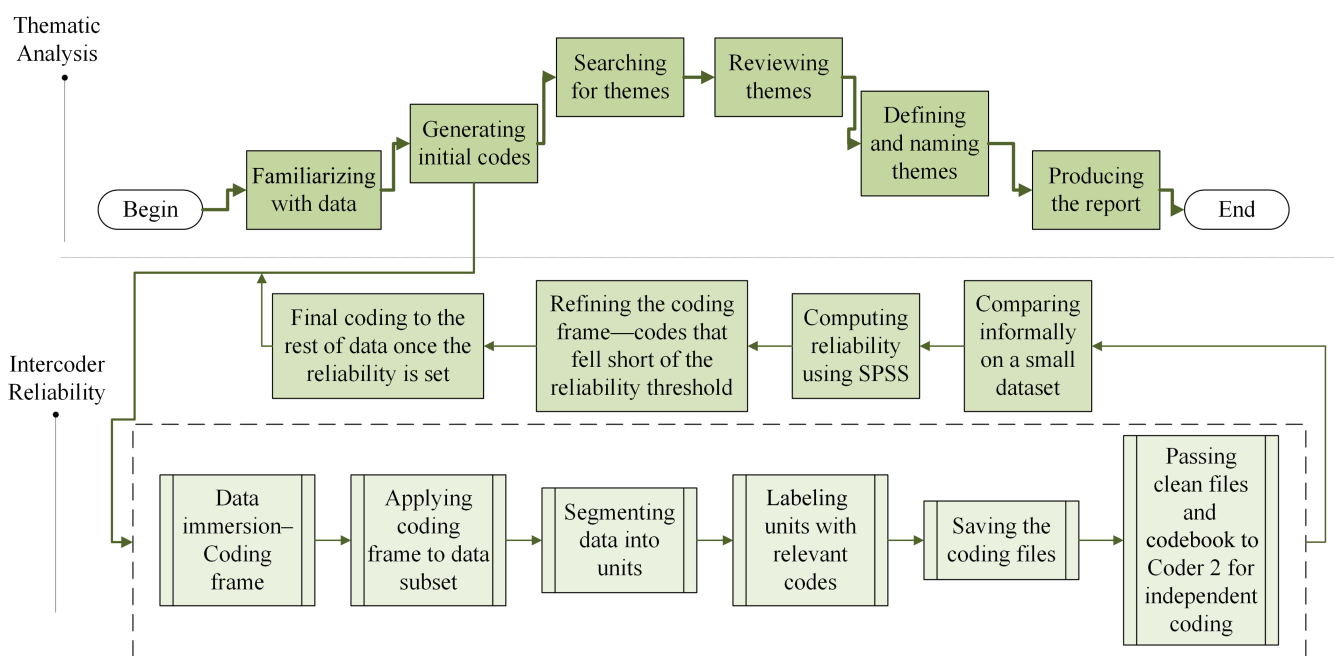


FIG. 1. Qualitative analysis process.

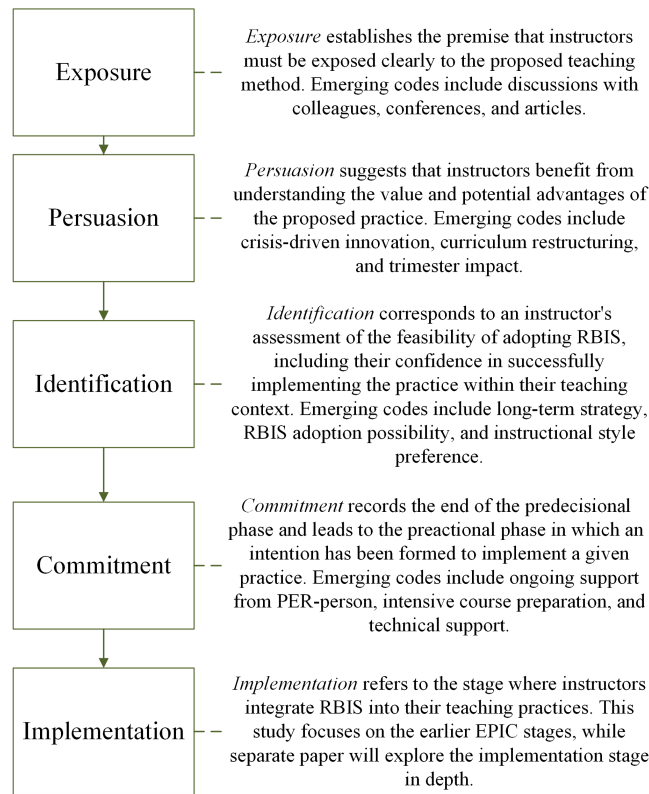


FIG. 2. EPIC-implementation model following [20].

The process followed the lighter-shaded stages as shown in Fig. 1, with discrepancies resolved through discussions between both authors. Initially, they conducted coding independently. The initial intercoder reliability was calculated using Cohen's kappa, which indicated 0.305 and falls in the minimum agreement category [39]. After a consensus discussion between the first and second authors, the agreement rate improved to 96%.

Instructors' statements that were aligned with the EPIC categories (or subcategories) were coded as either positive or negative within each category. The data are presented through a normalized bar chart (see Fig. 3), visually representing instructors' RBIS adoption profiles. Additionally, the Mann-Whitney test identified patterns in progression across stages for instructors with similar profiles, offering deeper insights into their instructional change journeys.

To interpret variation in instructional practice, instructors were qualitatively categorized into three groups: high users, low users, and nonusers of RBIS. This classification was determined through a multistep process. First, the initial categorization was based on instructors' self-reported teaching methods and their descriptions of exposure to, knowledge of, and engagement with RBIS during interviews. Second, these accounts were cross validated with course materials, including lecture notes, course outlines, and assessment instruments, to examine whether their descriptions aligned with documented practice. Third,

EPIC Stages-Normalized

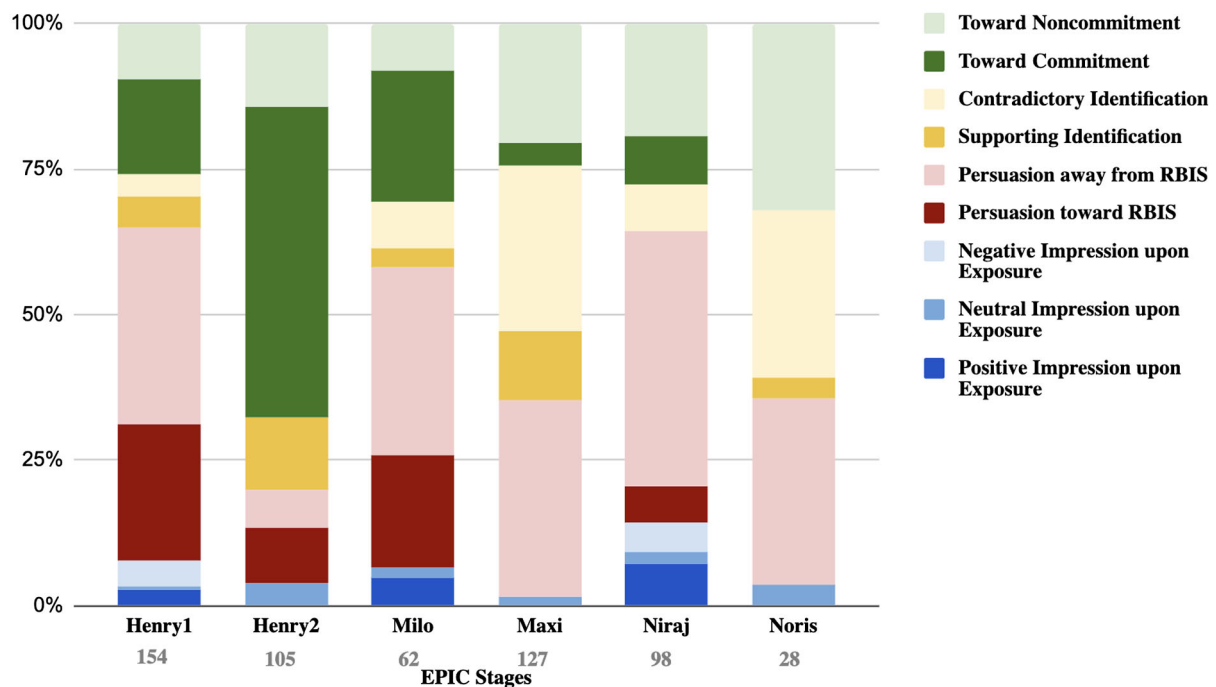


FIG. 3. Normalized distribution of excerpts based on the EPIC stages.

the research team reached consensus through collaborative discussion, including input from the third author, who has extensive experience in instructional change research. This approach was inspired by prior work on RBIS user classification, which emphasizes sustained use, selective or partial use, and nonuse [12].

The combination of interview data and course documentation enabled triangulation of implementation levels. Finally, Mann-Whitney U tests were conducted in SPSS to compare the distribution of EPIC-coded excerpts among user groups, providing an additional quantitative lens to compare instructor engagement patterns.

III. RESULTS

The instructors examined in this case study taught within second-year physics courses, providing a context where foundational review and disciplinary depth often intersect. In addressing the research question, “How and why did instructors navigate their choices regarding RBIS adoption?” we first present the normalized distribution of excerpt counts classified within the first four stages of the EPIC-implementation model (see Fig. 3).

Henry1 and Henry2 demonstrate a progression from initial skepticism to stronger commitment, with Henry2 showing greater confidence in integrating RBIS after overcoming early challenges. Milo aligns closely with Henry1, requiring less persuasion due to prior exposure, which facilitated a smoother adoption process. In contrast, Maxi and Niraj faced significant challenges in RBIS adoption. Maxi remained more skeptical and selective in implementation, questioning its effectiveness, while Niraj, despite initial enthusiasm, struggled with workload and content overload, limiting his ability to integrate RBIS into his teaching. Interestingly, Noris and Maxi, despite differences in their RBIS exposure, share a similar skepticism and preference for traditional teaching methods. Noris remained firmly committed to traditional instruction, questioning the relevance of RBIS, particularly in higher-year courses.

These variations in adoption patterns suggest that both individual teaching philosophies and institutional factors play a critical role in shaping instructors’ decisions regarding RBIS. A more detailed discussion follows in a later section.

A. Profiles summary

This section explores how instructors engaged with RBIS by comparing one profile to another. Whereas, the next three sections are structured according to the first four stages of the EPIC-implementation model: exposure, persuasion, identification, and commitment [20].

1. Henry: From initial engagement to evolving commitment

Henry’s case is unique in that it spans two time periods, reflecting a shift from early exposure to more sustained

implementation. While these stages are labeled “Henry1” and “Henry2” in comparative figures to reflect temporal differences, this section presents his development as a continuous narrative of evolving engagement.

Henry’s awareness of RBIS stemmed from peer discussions, professional conferences, and scholarly articles. Despite this exposure, Henry approached RBIS with initial skepticism, viewing it as potentially another passing educational trend.

The COVID-19 pandemic in Term 1 2020 marked a pivotal moment, prompting Henry to innovate in response to a rapidly changing teaching landscape. Henry faced significant time constraints, a demanding academic workload, and constraints from institutional structures. His initial efforts also highlighted the challenges of covering extensive course content within a condensed time frame and managing online teaching complexities. Despite these barriers, Henry demonstrated a willingness to adapt, driven by a strong commitment to lead by example in his teaching practices.

By his second engagement with RBIS, Henry’s successful implementation during the pandemic bolstered his confidence. Peer observations, conferences, and academic literature continued to shape his understanding. Henry identified flipped-classroom methods as a long-term strategy, integrating high-fidelity video production and workshop-based problem solving into his teaching. Despite the lack of institutional support, he remained committed to refining his course design, dedicating significant time to structuring lecture content, developing video materials, and optimizing his recording workflow.

2. Milo: Intrinsic motivation and institutional barriers

Milo’s engagement with RBIS was driven by his intrinsic motivation to enhance student learning. He was encouraged by the successful implementation of RBIS in tutorials by a teaching assistant (TA), who had collaborated with Henry1 before the term on the Flipped Classroom approach.

Having become aware of RBIS through peer discussions as early as 2015, Milo was initially cautious but open to its potential. Milo adopted student-centered methods that aligned with his values. However, he faced significant obstacles in managing pre-recorded material, sharing resources, and balancing his dual roles as a researcher and teacher.

Initially, Milo was concerned that students’ reliance on typeset notes—an integral part of his teaching approach—might encourage passive learning and create a false sense of mastery. Milo valued the structured instructional approach of RBIS and saw its potential to enhance student engagement. His belief in RBIS as a more effective strategy for fostering deeper engagement motivated him to explore its implementation further.

While Milo expressed a strong interest in RBIS and engaged in peer discussions, his course materials—such as lecture notes, course outlines, and assessment tasks—revealed that he implemented only selected elements of

RBIS. For instance, he incorporated preclass quiz and revisited it during class, with polls occasionally embedded to prompt interaction. Across a typical week, two class sessions were lecture-oriented, with interactive components more concentrated in the third. The classification of low user is informed by analysis of course documents and interview notes taken by the first and second authors. Although the interview was not digitally recorded, triangulation across these sources supports this interpretation of partial and component-based RBIS use.

3. Maxi: Skepticism and selective adoption

Maxi's journey with RBIS reflected a complex interplay of skepticism, selective adoption, and traditional preferences. With limited initial exposure, Maxi struggled to embrace RBIS fully, often expressing concerns about its effectiveness. His hesitation was influenced by his belief in subject expertise over active learning methods and his challenges in balancing teaching with research responsibilities.

Maxi identified challenges such as the extra workload of studying new methods and the difficulty of balancing these efforts with his research responsibilities. Maxi's resistance to online teaching further shaped his perception. Concerns about the effectiveness of RBIS in fostering long-term learning also influenced Maxi's views. He questioned whether recorded videos and other RBIS components merely encouraged short-term retention for exams.

Nevertheless, Maxi selectively adopted elements of RBIS, such as structured reflective tasks, which he acknowledged as beneficial for student learning. Peer support and workload-reducing technologies helped facilitate commitment, but the lack of technical support and his limited knowledge of RBIS principles hindered broader implementation. Maxi criticized generic teaching methods imposed by institutions, arguing that they often overlooked subject-specific needs. As a result, his approach remained guided more by practical considerations and traditional teaching methods than by a full personal commitment to RBIS.

4. Niraj: Enthusiasm undermined by practical barriers

Niraj's interaction with RBIS began with positive peer interactions and observations of its success in another course. These experiences initially sparked interest in adopting RBIS, particularly for its potential to enhance student engagement and analytical reasoning. However, this enthusiasm was tempered by significant practical barriers. High teaching workloads, content overload, and difficulties in maintaining student participation made it challenging for Niraj to effectively implement RBIS.

Niraj struggled to align his methodologies with his teaching context, particularly for highly mathematical subjects like the *Electromagnetism* course. While he introduced quizzes as a form of assessment, his broader adoption of RBIS was hindered by a lack of institutional support,

including insufficient training resources, inadequate structural incentives, and limited guidance on active learning implementation. His decision to revert to traditional methods highlights the critical role of institutional support and practical alignment in sustaining RBIS adoption.

5. Noris: Resistance rooted in tradition

Noris' experience provides a stark contrast to the other instructors. Noris' limited exposure to RBIS contributed to his cautious and skeptical approach. He questioned its relevance, particularly for higher-year courses, and preferred methods that aligned better with research-driven content, such as the generation of detailed lecture notes that aligned better with his research-driven outlook.

Noris remained unconvinced of RBIS's compatibility with his teaching style. Balancing academic responsibilities further complicated his willingness to explore RBIS, reinforcing his reliance on established practices. While Noris valued collaborative learning in principle, Noris decided against adopting RBIS, choosing to focus on familiar and proven teaching strategies instead.

Claim 1: *While instructors' EPIC profiles of initial engagement with RBIS may appear similar, their levels of RBIS adoption varied.*

The profiles of Henry1 and Milo, as seen in Fig. 3, reflect similar perspectives on RBIS initial engagement. A Mann-Whitney test comparing their profiles reveals no significant difference in the distribution of EPIC codes across categories, indicating aligned perspectives toward adopting RBIS. However, despite this similarity in early engagement, their levels of RBIS engagement varied.

Henry and Milo, the former and current teaching directors at the time of data collection, respectively, demonstrated a strong commitment to effective teaching practices. They co-taught the *Quantum Physics* course, with Henry1 handling the first half and Milo the second. Both instructors had prior exposure to RBIS and recognized its benefits in engaging students. Milo described RBIS as “*this is a great way to run the tutorials*,” emphasizing its positive impact on student engagement and feedback. Similarly, Henry1 ultimately embraced RBIS but required more persuasion, as indicated by the longer red section in his EPIC chart (see Fig. 3). Their experiences highlight how prior exposure and peer influence can facilitate RBIS adoption [14].

Both instructors also faced challenges in adopting RBIS. They acknowledged that transitioning from traditional teaching methods required effort and adaptation. Henry1 reflected on the discomfort of change, stating, “*Making that change forces you... You end up having to go back to not being very good for a while, until you can become good again.*” Milo, while committed to RBIS, raised concerns about the increased workload, particularly with prerecorded materials, describing them as “*adding more work to do due to the nature of the editing process.*”

Despite these shared experiences, Henry1 and Milo had different motivations for adopting RBIS. Henry1's adoption was heavily influenced by external factors, particularly the disruptions caused by the COVID-19 pandemic. He noted, "*Covid, in a sense, tipped everything on its head, and when everything's tipped on its head all of a sudden you can start to think differently. So, you know, had we not had Covid, I might not have done it, or I might have done it very differently at a much different pace.*" In contrast, Milo was internally driven by his belief in student benefits, stating, "*It is my own interest in why I do it. I like how students benefited from it ... You have to be personally motivated to do it.*"

Additionally, their level of institutional reliance varied. Milo found support in the growing community of instructors sharing innovative strategies, observing that "*Much bigger community now sharing ideas about teaching methods.*" Henry1, however, struggled with limited institutional support and relied heavily on informal networks. While he managed the actual implementation himself, he emphasized that regular guidance from an RBIS mentor was essential in structuring and sustaining the approach. He described this support as critical to both attempting RBIS in the first place and not abandoning it when challenges arose, explaining, "*Had I not had that, I wouldn't have done it at all.*"

Beyond providing expert advice on RBIS implementation, the experienced mentor also played a crucial peer-support role, helping Henry1 navigate uncertainties and setbacks. He recalled "*It was having someone whom I could go to after class and go, 'All this is a disaster,'*" highlighting how ongoing mentorship and reassurance were vital in sustaining his commitment to RBIS [40]. His experience reinforces a broader challenge in RBIS adoption—without access to experienced mentors who also provide practical support, many lecturers may abandon RBIS due to early difficulties [41].

Similarities are also evident in Maxi's and Noris' profiles, as shown in Fig. 3. While the Mann-Whitney test confirms these similarities, their responses to RBIS adoption differed significantly. Both had limited prior exposure to RBIS, valued structured teaching approaches, and recognized its potential to enhance student learning.

However, while Maxi selectively adopted RBIS elements, Noris rejected them entirely. Maxi, who co-taught with Henry2, integrated quizzes into his course after recognizing their benefits, stating, "*I adopted his quizzes ... It's actually very good because it means every week you think actually.*" Despite this adaptation, Maxi retained a primarily traditional lecturing style, as evidenced by his course materials shown in Fig. 8. His selective adoption of RBIS reflected an attempt to balance innovation with his existing teaching philosophy.

In contrast, Noris dismissed RBIS as unsuitable for university-level teaching, describing it as "*But you know*

these new methods of teaching. It's basically ... I sort feel like kindergarten stuff, and it's university, not kindergarten." Emphasizing individual student effort and traditional problem solving, Noris argued that students must 'work himself or herself' to succeed. Unlike Maxi, who incorporated aspects of RBIS, Noris, who lacked co-teaching exposure to an RBIS advocate, reinforced his reliance on conventional lecturing methods. His case illustrates how limited exposure to RBIS within a co-teaching setting can maintain skepticism toward instructional innovation [5,7,30,42].

In summary, Henry1 and Milo shared an initial openness to RBIS but differed in their motivations and reliance on institutional support. Henry1's initial adoption was externally driven and peer-supported, whereas Milo's was fueled by intrinsic motivation and institutional engagement. Milo's case illustrates how positive intent and philosophical support for RBIS may not translate into full adoption, particularly when workload constraints and limited implementation experience are present. Similarly, Maxi and Noris, while having similar profiles towards RBIS, responded differently. Maxi selectively integrated RBIS elements while maintaining traditional methods, whereas Noris, lacking advocacy exposure, remained committed to conventional lecturing. These cases underscore the critical role of peer collaboration and institutional context in shaping instructional decisions, suggesting that qualitative approaches may be particularly useful in capturing nuanced adoption patterns that structured quantitative instruments might not fully reveal.

B. Sustaining commitment: Lessons from repeat implementation

Claim 2: *Successful implementation of RBIS the first time can support its use in future courses, with an even stronger commitment.*

This section traces Henry's RBIS adoption across two teaching contexts: an initial implementation in one course and a subsequent, more confident application in another. While these are coded as "Henry1" and "Henry2" in Fig. 3, the narrative here presents his journey as a continuous trajectory.

Henry's exposure to RBIS came from a mix of formal and informal channels, as illustrated in Fig. 4. Formal sources, such as educational conferences (E6) and scholarly literature (E7), provided valuable insights into RBIS [24,43,44]. Henry described the role of conferences, saying, "*You hear about it at educational conferences, that sort of thing.*" Additionally, articles and books informed Henry's understanding of RBIS, as he noted, "*You go read some articles... read a book or two.*"

Informal exposure also played a significant role, particularly peer observation (E5) and departmental discussions (E1). However, skepticism about the longevity of certain teaching methods occasionally surfaced (E4). Henry

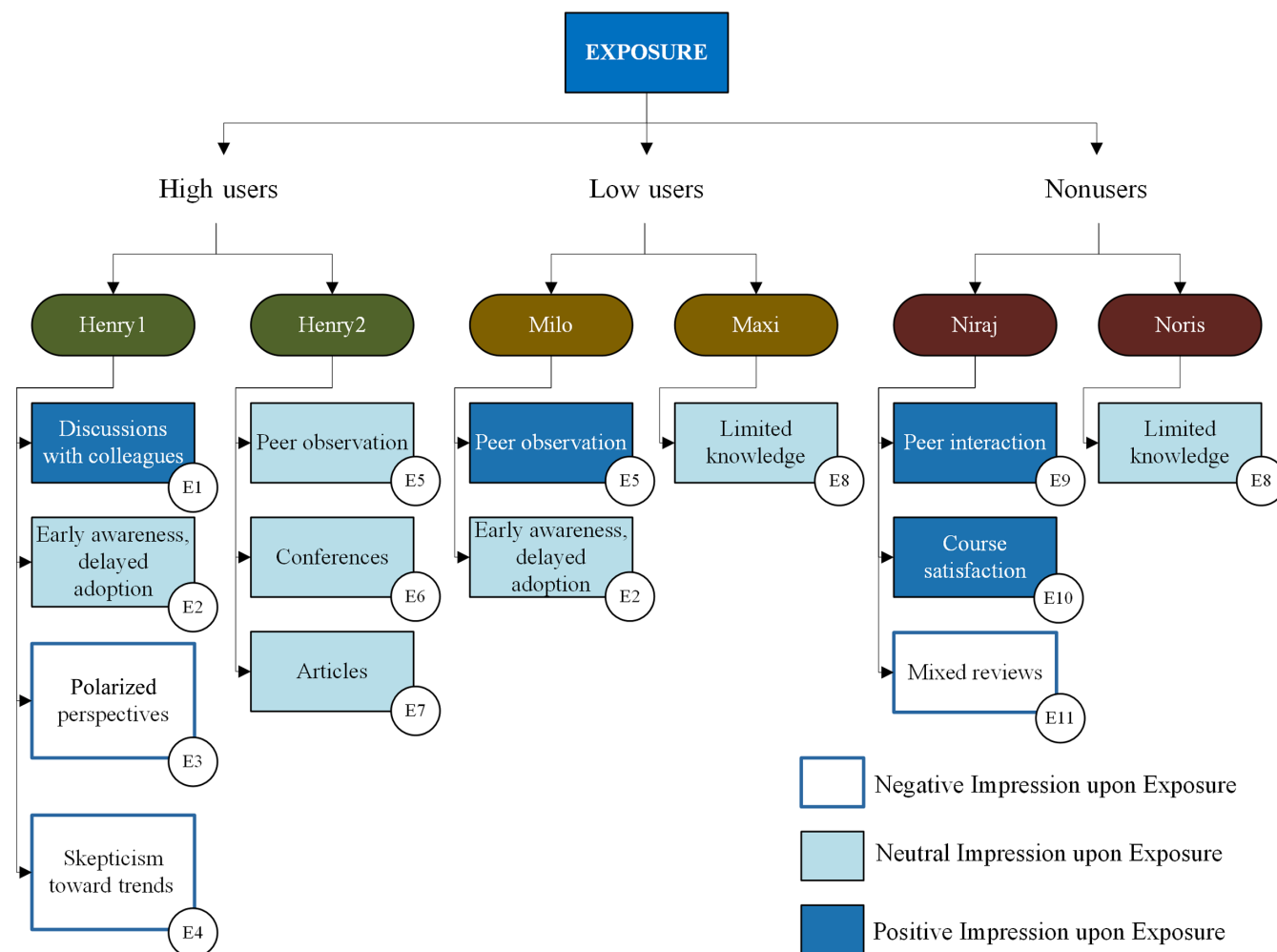


FIG. 4. Top coded subcategories in the exposure stage for each instructor.

shared his doubts, stating, “And I’m like, you know, do these things really work ... they’ve always seemed to me like a fad that comes in and then goes out ... Clickers, for example ... in two years you’d walk in and just find this box of clickers gathering dust ... fad comes, fad goes.”

Figure 3 highlights Henry’s progression in RBIS adoption. His initial engagement, coded as “Henry1” in Fig. 3, was dominated by the persuasion stage, reflecting the significant effort required to overcome initial barriers. In Term 1 of 2020, Henry completed most of his portion of teaching *Quantum Physics* before the unexpected transition to lockdown. Consequently, the initial EPIC stages—exploration, persuasion, identification, and commitment—primarily took place during his nonteaching period in the second half of *Quantum Physics*. His first implementation of RBIS occurred in *Classical Mechanics and Special Relativity*. During this period, Henry explored curriculum restructuring (P5) (see Fig. 5). He identified the potential for long-term sustainability in the video-based teaching strategy (I2), as shown in Fig. 6, and adopted a flipped-classroom model in response to pandemic-driven

challenges. After experiencing the benefits of RBIS during its initial implementation, his commitment strengthened in the next engagement—the 2021 *Quantum Physics* course.

At this stage, Henry struggled with limited institutional support (C3), as illustrated in Fig. 7, which hindered sustained use of RBIS. Henry criticized the superficial nature of support systems, stating, “It goes from apathy to fake support ... when you ask for anything to help, no one cares.” This perceived apathy led to frustration and reduced motivation, as Henry noted, “That’s more about the appearance than the reality ... No one cares.”

Despite the challenges, Henry’s commitment to RBIS was evident in the substantial time and effort dedicated to its implementation (C26). Reflecting on the preparation required, Henry stated, “There was probably something in the vicinity of four to six weeks lead up time ... Probably about one or two weeks out before the course I started recording the series and basically my aim was to try and make sure that I stayed at least a week ahead.” This meticulous planning underscores Henry’s determination to ensure the success of RBIS in his courses.

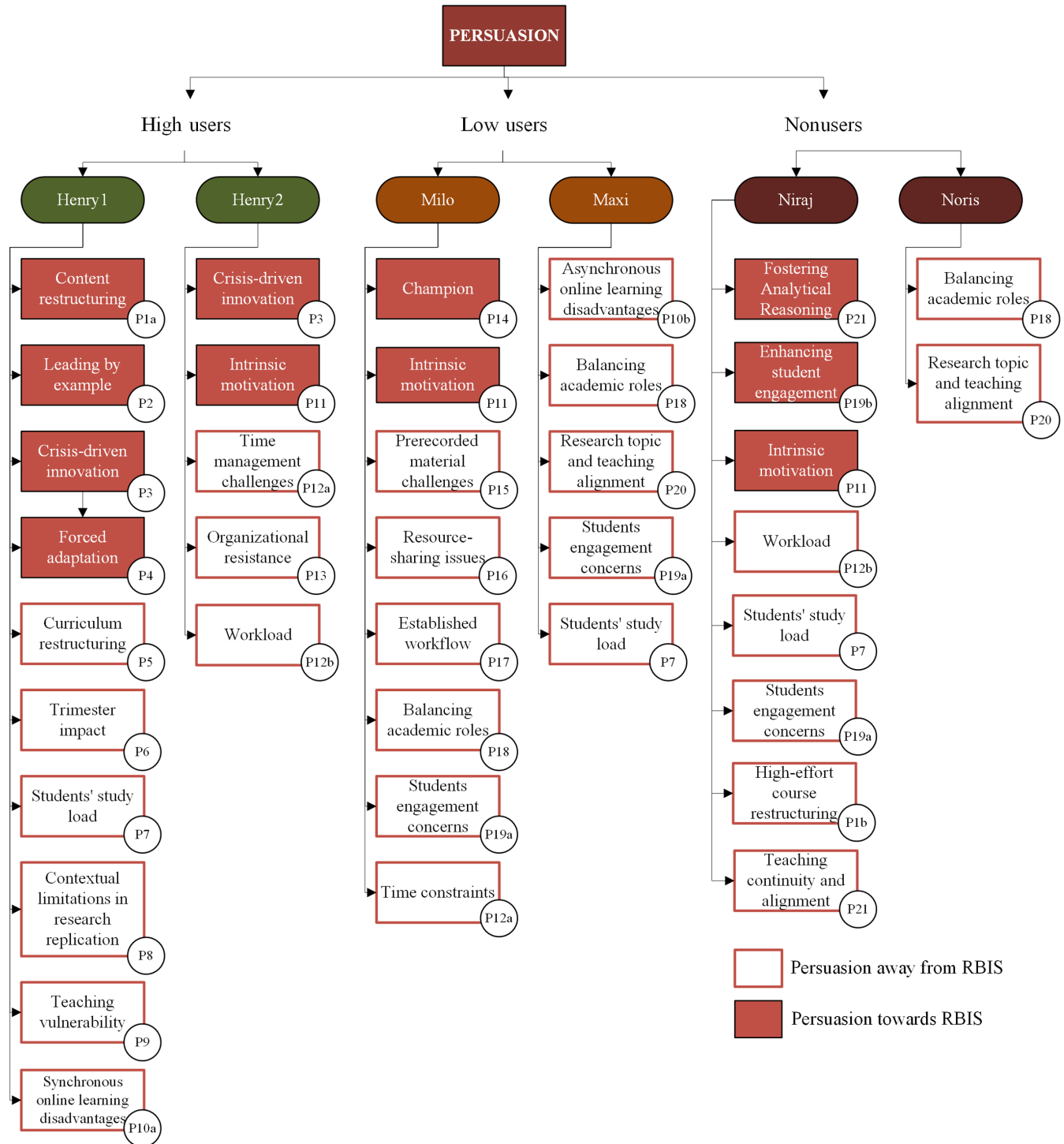


FIG. 5. Top coded subcategories in the persuasion stage for each instructor.

In his second engagement, coded as “Henry2” in Fig. 3, the persuasion stage was far less dominant, signaling a shift in perspective. Henry displayed greater confidence and alignment with RBIS principles across other stages of the EPIC framework. This growing familiarity and comfort with RBIS adoption enabled Henry to navigate the process with more ease.

During the second engagement, Henry demonstrated a clear positive alignment in the identification stage, with no contradictions in values regarding RBIS adoption. The prior successful implementation bolstered Henry’s commitment to using RBIS consistently in the subsequent *Quantum Physics* course.

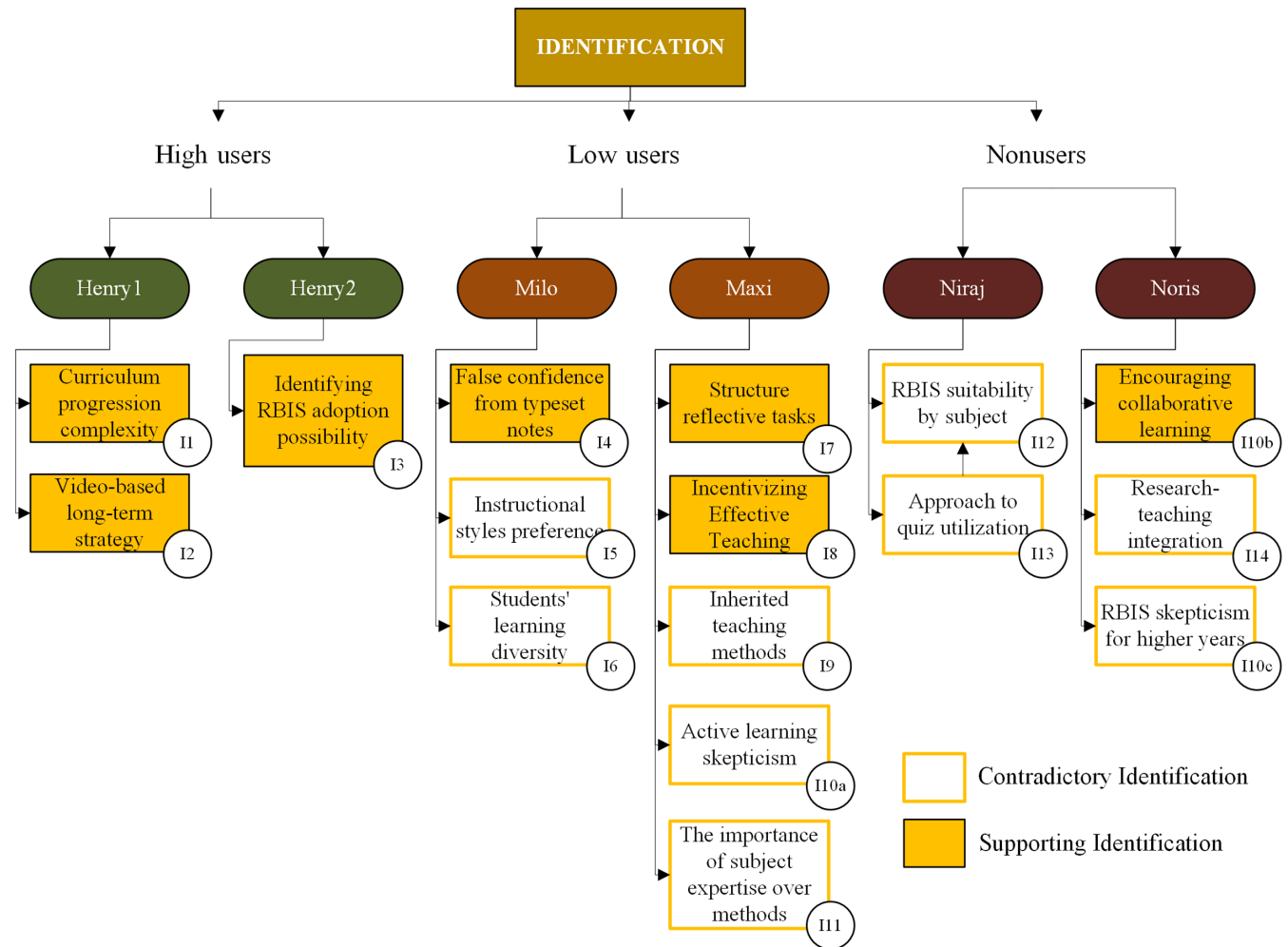


FIG. 6. Top coded subcategories in the Identification stage for each instructor.

C. Co-teaching as an effective means of RBIS exposure

Claim 3: *Co-teaching influenced the adoption of RBIS.*

Co-teaching has been recognized as an effective mechanism for promoting instructional change, as it provides instructors with direct exposure to new teaching strategies through collaboration with more experienced colleagues [16]. In this study, co-teaching emerged as a significant factor in shaping RBIS adoption, impacting instructors' exposure, adaptation, and integration of these strategies into their teaching practices.

Henry's co-teaching experiences in the *Quantum Physics* and the *Classical Mechanics and Special Relativity* demonstrate how co-teaching can shape RBIS adoption. This influence was particularly evident in the *Classical Mechanics and Special Relativity* course, where Henry2 co-taught with Maxi.

Figure 8 illustrates the differences in course design choices between Henry2 and Maxi in their respective halves of the *Classical Mechanics and Special Relativity* course. Henry2, a high user, structured his half with a mix of interactive learning components, such as video-based

lectures, structured problem-solving sessions, and weekly tasks. In contrast, Maxi maintained a more traditional lecture-based approach, supplementing with weekly quizzes but minimizing a structured active learning approach. This contrast reflects how co-teaching influenced Maxi's partial adoption of RBIS. While he integrated certain elements, he did not fully commit to the approach, aligning with his pre-existing teaching philosophy and skepticism toward online instructional methods.

Despite these reservations, Maxi acknowledged the value of reflective tasks implemented by Henry2 during the first half of the course (I7), which he sought to maintain. While he recognized the benefits of frequent quizzes for lower-level courses, Maxi questioned their applicability for more advanced students, stating “*They eventually... connect things from one week to another... [quizzes] are definitely a good idea for lower level courses.*”

Maxi's commitment to refining his teaching was evident. He described the challenges of teaching unfamiliar material (C8) but remained dedicated to delivering effective instruction, saying, “*Cause yeah, I just never used it in my*

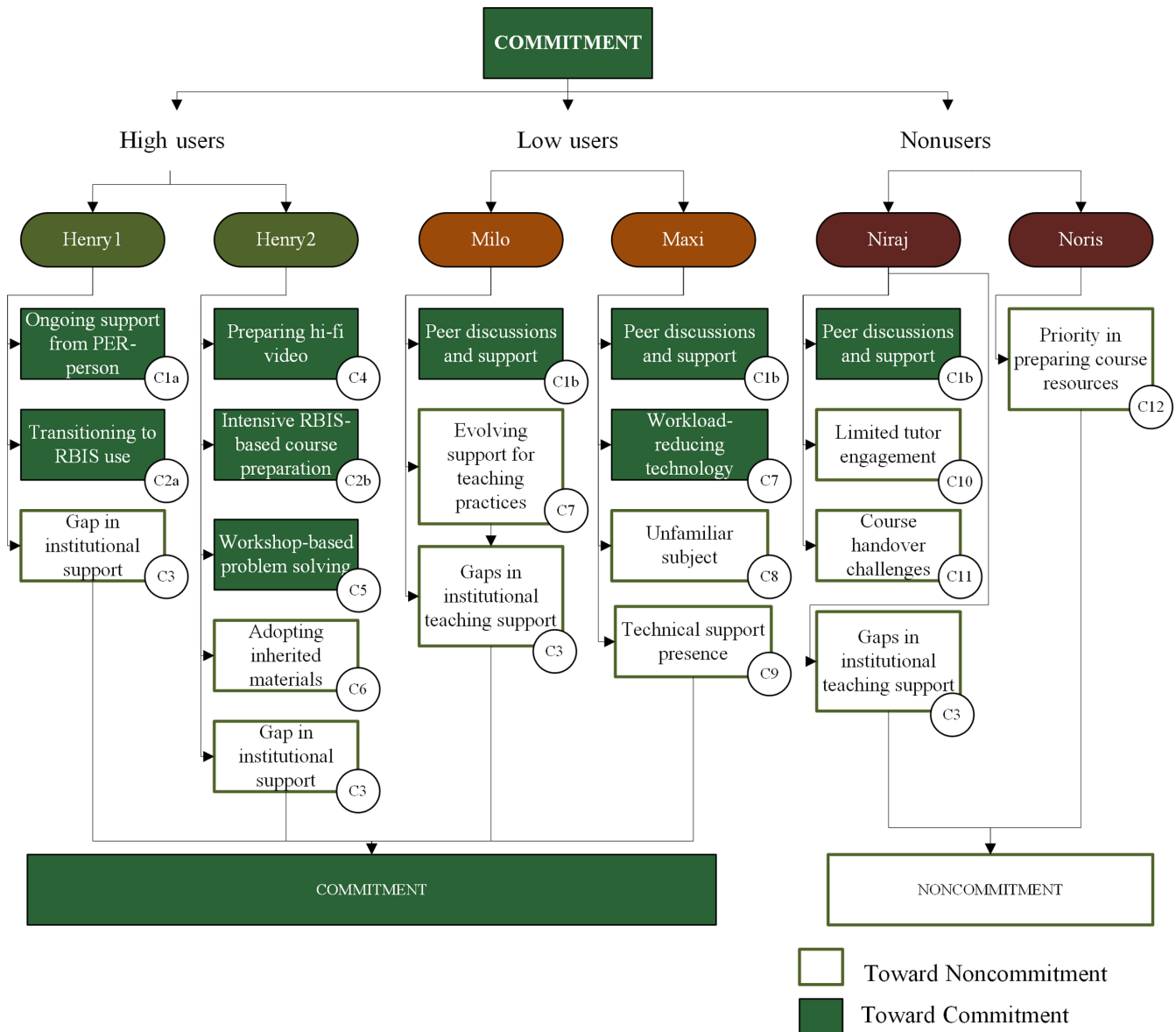


FIG. 7. Top coded subcategories in the commitment stage for each instructor.

research... that was in the way I have to teach myself at the beginning.” However, his preference for traditional teaching methods led to a modified RBIS implementation that aligned better with his style [21].

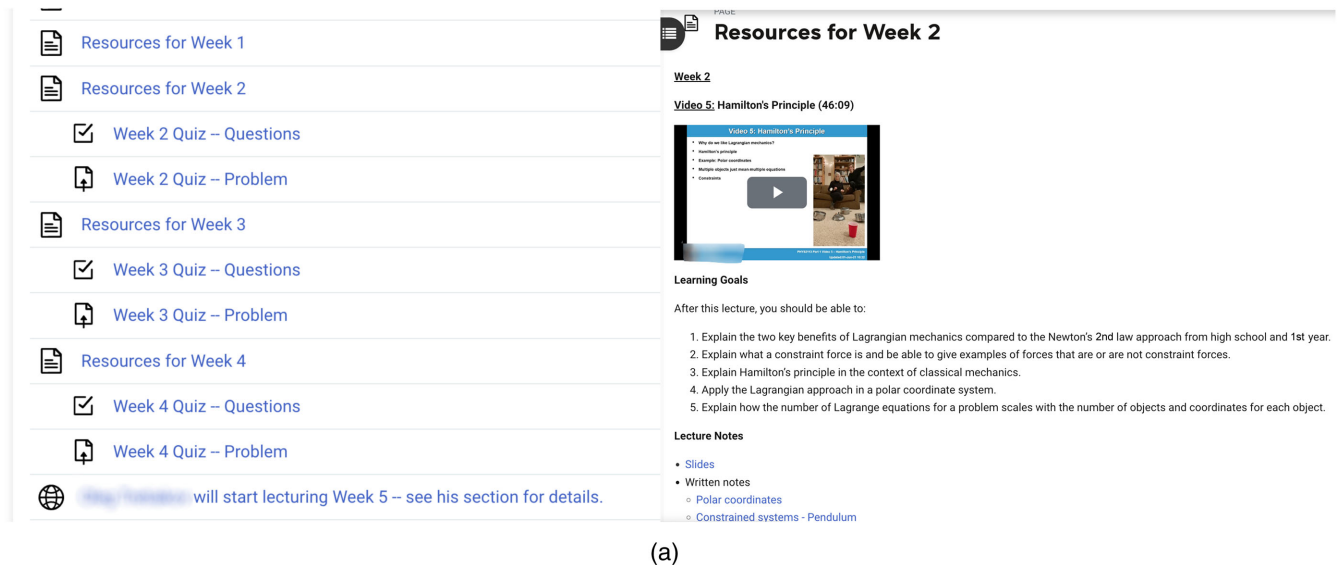
A reliance on established teaching practices (I9) was a recurring theme in Maxi’s approach. He reflected, “I just follow, what was established before because usually... people teach this course for several years, so it’s already [set].” This tendency to adhere to familiar methods, combined with his skepticism, defined his cautious engagement with RBIS.

A similar pattern emerged in Milo’s teaching. While Milo displayed a more positive outlook on RBIS, he also modified its implementation to fit his teaching style, blending it with traditional methods. Both instructors, Milo and Maxi, adopted RBIS despite their differing

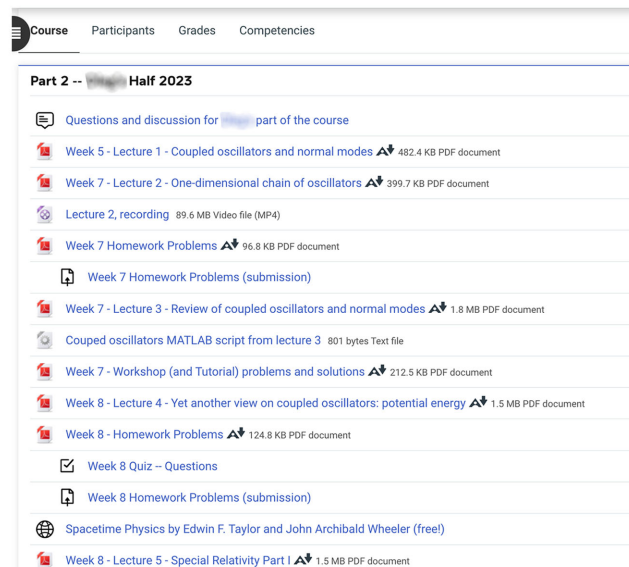
attitudes, modifying it to align with their individual teaching preferences.

Co-teaching proved to be a double-edged sword. Maxi’s and Milo’s collaboration with Henry, a high user of RBIS, positively influenced their decision to adopt and adapt RBIS. In contrast, the dynamic between Noris and Niraj was different. Noris, who lacked a co-teaching partner familiar with RBIS, maintained a traditional lecturing style. Noris’ strong skepticism towards RBIS was evident, particularly in his belief that such methods were unsuitable for university-level teaching (I10c).

This skepticism extended to his co-teaching partner, Niraj, who taught the first half but joined the teaching team later than Noris. Although Niraj initially viewed RBIS positively due to prior collaboration with an RBIS mentor in another course, he ultimately reverted to a lecturing approach.



(a)



(b)

FIG. 8. Course resources in (a) Henry2's half and (b) Maxi's half.

The lack of institutional support (C3) further influenced this decision [18]. Niraj articulated his frustration, stating “No, there was no one basically. It was just like, I mean, here’s the Moodle site ... Nothing like that allows people to take over a course and get used to things.”

Through these narratives, it becomes evident that co-teaching can either foster RBIS adoption or reinforce traditional practices, depending on the presence of an advocate and the level of institutional and peer support.

D. External impact on RBIS adoption

Claim 4: *Broader external factors posed significant challenges.*

While the EPIC-implementation model acknowledged external influences, it does not integrate them as core components, instead assuming they naturally shape instructors’ engagement with teaching innovations. However, broader systemic, contextual, and environmental factors—such as institutional policies, room allocation, scheduling constraints, and infrastructure limitations—emerged as significant challenges in this study, directly impacting instructors’ ability to implement and sustain RBIS. Despite these limitations, the EPIC-implementation model remains valuable tool for analyzing RBIS adoption, as it provides a structured framework to examine how instructors progress through key stages of instructional change.

Institutional barriers, such as high workloads, insufficient training, and a lack of rewards for teaching excellence, emerged as persistent systemic challenges. These barriers operate alongside contextual factors—such as co-teaching arrangements and departmental expectations—as well as environmental influences, including national education policies and global disruptions. For example, instructors struggled with misaligned incentives (a systemic issue), departmental constraints on curriculum flexibility (a contextual issue), and shifting teaching expectations due to post-pandemic educational reforms (an environmental factor).

The challenges of balancing research and teaching responsibilities emerged as a significant barrier to RBIS adoption. Many instructors prioritized their research, leaving limited time and effort to invest in new teaching strategies (P18) [19]. Milo articulated this reality, stating, “*Instructors can’t do all these methods. They are primarily employed as researchers.*”

The issue was compounded by a lack of proper training in effective teaching practices, which left many instructors unprepared to adopt RBIS [1,2,5,43]. Milo highlighted the need for more comprehensive training, observing, “*They have no training in good teaching practices. Some instructors are employed as researchers; it might require more training.*”

Broader institutional challenges further hindered RBIS implementation. A fast-paced academic environment (P6), frequent changes in course structures (P5), and the overall organization of the university teaching system created additional obstacles [24,45]. Henry reflected on these difficulties, explaining, “*It’s all of the over-pinning things of having to deal with your organization as a whole.*” He added, “*And then there was the big global 3+ change, which I would say was basically ‘throw things overboard or the ship will sink’ approach.*”

High teaching workloads (P12b) and the short-term focus of academic roles left instructors with little room to innovate [10,30,46,47]. Niraj captured this struggle, saying, “*So because there’s so much and I’m struggling to finish up material from one lecture to another.*”

A lack of meaningful incentives for good teaching also weakened instructors’ commitment to RBIS [19,23,25]. Maxi emphasized the importance of recognition, stating “*It’s better to reward people for good teaching. That’s true.*” Without such rewards, the motivation to engage deeply with RBIS dwindled, highlighting a gap in institutional support (C3).

Another consideration was the appropriateness of RBIS for different content and contexts [17,42,48]. Instructors acknowledged that teaching methods need to align with course material (I12). Niraj noted, “*I mean with the Electromagnetism, I think flipped classroom is probably not the best way to go because you have a lot of math that needs to be worked out and everything. If it’s more concept based then flipped mode works well basically.*” Maxi echoed this view, adding, “*But again, you cannot, even*

if you do formally. All these ingredients of what’s nowadays called active learning. If you don’t know much of physics, you can’t teach physics because you were never a good researcher.”

These contextual factors—ranging from departmental barriers and workload challenges to content-specific considerations—collectively shaped instructors’ attitudes and decisions toward adopting RBIS. While some instructors showed interest in RBIS, the systemic obstacles often undermined their ability to commit fully to its implementation.

E. Limitations

This study is shaped by certain boundaries. First, its focus on a small group of instructors may limit the generalizability of the findings to broader contexts. Second, the reliance on self-reported data introduces the possibility of subjective interpretations, as participants’ perspectives may not fully capture objective realities.

IV. DISCUSSION

This discussion interprets instructor engagement with RBIS through the EPIC-implementation model, focusing on how individual trajectories are shaped by both personal commitments and institutional contexts. Section IV A examines variation in instructor engagement across EPIC stages. Section IV B explores the systemic and environmental factors that influenced these patterns. Section IV C builds on these insights to propose an augmentation of the EPIC model that accounts for institutional and cultural dynamics drawn from broader reform literature.

A. Individualized adoption of RBIS: Challenges and hesitation

RBIS adoption and sustained use are influenced by a complex interplay of individual motivations, institutional dynamics, and broader contextual factors. At the individual level, instructors’ engagement with RBIS was shaped by exposure through peer interactions, academic conferences, and scholarly literature, as well as their personal teaching philosophies and professional roles [4,18,49]. While some instructors were encouraged by leadership roles or inspired by observing successful implementations, others remained skeptical or indifferent due to limited exposure. Additionally, instructors’ perceived freedom to innovate was often moderated by status—tenured faculty or those with disciplinary credibility reported more autonomy, whereas early-career instructors tended to conform more closely to institutional expectations, especially regarding research productivity [50]. However, initial awareness alone was often insufficient for full adoption—additional persuasion and alignment with teaching contexts were necessary before commitment to RBIS could be established.

During the identification stage, instructors' alignment with RBIS varied, influenced by both teaching philosophies and subject-specific challenges. Some gained confidence in RBIS, recognizing its potential to enhance student engagement and address limitations of traditional lecturing [18,21]. Others selectively adopted RBIS elements that fit with their instructional style, leading to partial rather than full implementation. This selective approach reflects how instructors balance innovation with existing teaching identities and competing priorities. Instructors were more receptive to instructional reform when it improved upon current practices, supported collaboration, and was compatible with existing resources—highlighting the importance of perceived alignment with familiar methods and shared goals [51].

To navigate RBIS adoption effectively, instructors benefit from peer networks, structured mentorship, and ongoing professional development. Incremental implementation and reflective practice can build confidence, while adapting RBIS to specific teaching contexts helps mitigate initial resistance and enhance long-term commitment [52,53]. In some cases, individual agency—such as strong motivation, mentoring, or prior pedagogical training—helped instructors overcome institutional constraints and maintain commitment to RBIS even in less supportive environments [50].

This study highlights how teaching philosophies influenced instructors' RBIS adoption. Instructors who perceived RBIS as complementing their pedagogical values exhibited stronger commitment, whereas those who found it misaligned often reverted to traditional methods [54]. Additionally, early experiences with RBIS—whether positive or negative—shaped long-term adoption trajectories.

While instructors often shared similar initial perspectives on RBIS, their outcomes varied significantly based on personal motivation, exposure to successful examples, and institutional support [12]. Instructors who successfully adopted RBIS tended to sustain its use and demonstrate greater long-term commitment, highlighting the role of confidence gained [55]. Meanwhile, those who struggled with the implementation challenges often withdrew or modified their approach [18]. Short-term faculty development efforts—especially when isolated or lacking follow-up—often fail to support sustained change, leading many instructors to revert to traditional methods when difficulties arise [56]. Notably, hesitation persisted among those who engaged with RBIS, suggesting that lasting adoption requires modest initial goals and continuous reinforcement through peer collaboration and institutional networks [56].

B. Key factors shaping RBIS adoption: Systemic, contextual, and environmental factors

While Sec. IVA focused on instructors' individual trajectories of engagement, this section shifts attention to the systemic, contextual, and structural conditions that

shaped those trajectories. The study underscores the importance of institutions addressing the interconnected influences of systemic, contextual, and environmental factors on RBIS adoption. Systemic reforms—such as reducing administrative burdens, expanding professional development opportunities, and formalizing instructional support structures—can reduce barriers to adoption. Institutional barriers, such as high workloads, insufficient training, and a lack of incentives for teaching excellence, remain a persistent challenge to RBIS adoption [18,19,23,49]. Consistent with prior findings, time constraints emerged as the most dominant obstacle across departments, often cited alongside concerns over instructional challenges, fears of losing autonomy, and resistance to change [51]. These constraints limit faculty engagement and contribute to selective or partial implementation of RBIS [18,49].

However, instructors do not need all barriers removed to implement RBIS. Recent research suggests that perceived support may play a more critical role in enabling adoption than the actual removal of obstacles. Amplifying supports—such as peer networks, resource visibility, and training for incremental implementation—can more effectively foster RBIS uptake than exclusively focusing on barriers. Creating support-rich environments, rather than attempting to eliminate every challenge, offers a more pragmatic and scalable approach to change [57].

In a university context where institutional support is limited, the most effective strategy to promote RBIS uptake is to prioritize interpersonal, peer-driven support systems. While systemic obstacles such as high workload, disorganized course handovers, and rigid assessment structures can certainly constrain innovation, evidence from this study indicates that the presence of human support—particularly collegial mentoring, emotional reassurance, and targeted pedagogical guidance—plays a far more decisive role in sustaining RBIS use. These forms of practical and moral support not only built confidence but also helped buffer early setbacks and foster ongoing reflection. In contrast, instructors who were philosophically open to RBIS were often stalled by the lack of structured support, even in the presence of partial barrier removal.

Instructors who perceive stronger institutional support for teaching are also more committed to instructional innovation. When teaching effectiveness is given greater weight in personnel decisions, instructors are more likely to value teaching and engage with external sources of innovation [58]. Yet in low-support environments where such institutional reinforcement is absent, the findings here suggest that change is most sustainably driven through grassroots, relationship-based structures. This includes mentoring partnerships, regular post-class debriefs, informal but intentional peer coaching, and small-team instructional planning. While structural reforms and workload adjustments are certainly desirable, they are not sufficient alone—particularly when instructors face competing

demands or philosophical ambivalence. Even when structural reforms are introduced, they may have a limited impact if instructors hold strong philosophical resistance to RBIS and perceive it as incompatible with their views on university-level teaching. Thus, fostering support-rich environments—especially at the level of departmental teaching teams—emerges as a more actionable and high-leverage approach to promoting instructional change in undersupported institutional settings.

In the absence of structured support, instructors relied on informal networks or personal efforts, placing a substantial burden on individual initiative and limiting the scalability and sustainability of instructional change. While individual motivation is crucial, sustainable RBIS adoption requires institutional commitment through structured support systems. Prior research has shown that continuous faculty development and institutional encouragement are necessary to overcome skepticism and support long-term adoption [24,47].

Efforts to promote RBIS adoption must address known barriers—such as workload, policy alignment, and institutional culture—while also considering the individualized nature of instructional change. As faculty responses to instructional reform often vary by department, localized teaching cultures play a critical role in shaping both resistance and momentum. For instance, some departments emphasized a lack of resources, while others pointed to limited pedagogical confidence or cultural resistance—highlighting the need for tailored strategies [51]. Aligning individual efforts with institutional structures and fostering co-teaching opportunities can further promote RBIS adoption in higher education [18,30].

Prior studies have identified persistent gaps between available supports and faculty needs [58]. Many instructors reported low use of accessible supports—such as internal technology grants or sabbaticals—while resources like course development grants or formal pedagogical training were often unavailable. Senior faculty were also less likely to value teaching or have received pedagogical training, highlighting the need for institutional reform across career stages.

In this context, co-teaching emerged as another influential mechanism in shaping RBIS adoption. Co-teaching played a dual role in RBIS adoption, either fostering it through positive mentorship or reinforcing traditional methods. When structured effectively, co-teaching can support faculty development by promoting best practices and encouraging gradual adoption of RBIS [30]. However, without intentional structuring, co-teaching may instead reinforce existing practices, limiting opportunities for instructional innovation.

Beyond workload distribution, co-teaching benefits students by exposing them to diverse teaching styles, research perspectives, and areas of expertise. This approach broadens their academic experience, potentially influencing their

future learning and career aspirations in physics. Co-teaching is implemented across all years, including the mathematically intensive second-year physics curriculum.

Broader contextual factors, such as the COVID-19 pandemic, accelerated RBIS adoption in varying ways. For some instructors, the shift to online teaching created opportunities for pedagogical experimentation, while others saw it as a temporary adjustment rather than a lasting change [59–61]. These differing responses underscore both the potential and the perceived limitations of RBIS in content-intensive disciplines like physics. Considering these variations is essential when developing long-term strategies for supporting instructional change at institutional and policy levels.

Resistance and skepticism toward RBIS further hindered adoption. Concerns over RBIS's effectiveness in advanced courses, its perceived status as a passing trend, and challenges with online implementation discouraged initial engagement and reduced long-term commitment. Content-heavy courses in physics further complicated RBIS adoption, as active learning strategies were often perceived as incompatible with intensive problem solving or advanced topics [42,48].

In the commitment stage, instructors exhibited varying levels of dedication to sustaining RBIS practices. Some invested significant time and effort into preparation and implementation, while others maintained traditional methods, often citing challenges such as limited institutional support and a lack of meaningful incentive. Notably, instructors who encountered positive student feedback were more likely to persist in their RBIS efforts, reinforcing the role of student engagement in shaping long-term adoption [18].

Taken together, RBIS adoption is influenced by a complex interplay of individual, institutional, and contextual factors, making universal implementation strategies challenging [18,62]. To ensure sustainable adoption, it is essential for policymakers to provide structured training, adjust workloads, and offer incentives that align with faculty priorities. Additionally, policies should be tailored to discipline-specific challenges, fostering a culture of innovation and collaboration to facilitate the practical integration of RBIS [7,63].

However, policy advocacy must also be grounded in practical, department-level realities. Rather than relying solely on centralized mandates, universities can empower local actors—such as teaching directors, course conveners, and peer mentors—to lead RBIS change efforts. These individuals are well positioned to identify structural mismatches, advocate for manageable course loads, and codevelop instructional support systems tailored to their contexts. Departments can formalize this work through teaching innovation committees, reward structures, and protected time for faculty collaboration. At a broader level, deans and teaching leadership teams can partner with

national networks to coordinate institutional policy alignment and promote evidence-based teaching as a shared priority. In this way, both top-down policies and bottom-up strategies can converge to support lasting instructional change.

C. Augmenting the EPIC model with systems and contexts

While Sec. IV B examined how contextual and institutional factors shaped RBIS engagement in our study, this section considers how the EPIC framework can be augmented to better account for systems-level dynamics. By employing an in-depth, qualitative analysis, this study explores individual instructor experiences within the first four stages of the EPIC-implementation model, demonstrating that RBIS adoption is neither linear nor uniform but shaped by dynamic interactions between personal motivations, peer influences, and institutional constraints. Prior research highlights faculty motivation and systemic influences as key factors in instructional changes [12,20], yet this study extends this understanding by illustrating how instructors' perceptions and experiences influence the adoption process at a deeper level.

The EPIC-implementation model provides a valuable lens for understanding RBIS adoption, particularly in analyzing individual motivations, systemic barriers, and adoption stages. It captures key decision-making factors such as exposure to successful examples and alignment with teaching philosophies [20]. However, broader systemic reforms and complementary frameworks are necessary for sustained teaching innovation. EPIC's primary focus on internal processes limits its ability to fully address contextual and environmental influences—such as institutional policies, cultural dynamics, and the long-term sustainability of instructional changes.

Building on the situated barriers and supports described in Sec. IV B, this study revealed additional factors beyond the EPIC model's original scope, including resource constraints and co-teaching dynamics, which influenced adoption trajectories but are not explicitly emphasized within EPIC's stages [30]. These findings suggest that while the model is a useful tool for analyzing adoption, additional considerations are needed to fully capture broader systemic and contextual influences.

To bridge the gap between individual commitment and institutional challenges, departments and universities must take a more proactive role in supporting instructional change. Providing discipline-specific training, structured mentoring, and recognizing teaching excellence can facilitate a more sustainable approach to RBIS adoption.

The Science Education Initiative (SEI) illustrates how departmental transformation can be achieved through sustained pedagogical support. The program embedded discipline-specific postdoctoral fellows—known as Science Teaching Fellows—within science departments

to collaborate with faculty on course design, implementation of RBIS, and assessment. This structure enabled departments to develop sustained, context-sensitive change strategies while engaging faculty in iterative improvement processes [64]. Pedagogical training during graduate school further increases faculty engagement with instructional development and consultation with peers [58].

The TRESTLE project (Transforming Education, Stimulating Teaching and Learning Excellence) extended this approach to a multi-institutional scale. TRESTLE emphasized local expertise, peer mentoring, and faculty learning communities as levers for instructional improvement. It combined department-embedded pedagogical support with cross-institutional collaboration, promoting both individual instructor growth and departmental shifts in teaching culture. Findings from the TRESTLE initiative demonstrated how strategic supports can foster broader systemic change, even in research-intensive environments [65].

Another impactful model is the Summer Institute (SI), launched in 2004 through a partnership involving the Howard Hughes Medical Institute, the National Academies, and the University of Wisconsin-Madison. The SI trained biology faculty in learner-centered, evidence-based teaching practices, focusing on course redesign using “scientific teaching.” Participants developed clear learning goals, interactive strategies, and effective assessment methods. Alumni of the SI actively shared their learning, organizing workshops, mentoring peers, and sustaining dialogue across departments. Within two years, 89% had mentored colleagues, illustrating the program's lasting influence in cultivating a community of practice [66].

These models provide sustained mentorship and support, addressing both individual experiences and systemic challenges in RBIS adoption. However, such efforts must be tailored to local teaching cultures, workload constraints, and institutional priorities to ensure long-term success.

In summary, the EPIC-implementation model remains a valuable tool for understanding RBIS adoption at the individual level. Its application in this study, however, highlights areas where additional frameworks or refinements may be beneficial. By bridging the gap between individual motivations and broader institutional and contextual factors, this study offers new insights into the interplay of personal agency, collaborative teaching structures, and systemic influences in shaping RBIS adoption. It suggests that instructional change frameworks should address institutional inertia and structural barriers to reform.

D. Future work

This study provides a foundation for understanding the adoption stage of RBIS through the EPIC-implementation framework. However, further research is needed to deepen insights into how instructional change unfolds beyond initial adoption and how broader institutional and environmental factors sustain or hinder these efforts.

First, a follow-up study will focus on the final stage of the EPIC-implementation model, emphasizing how instructors translate their commitment to RBIS into sustained practice. This work will examine the practical challenges of implementation, instructors' iterative refinements, and the role of institutional structures in supporting or limiting long-term RBIS use. Investigating this critical phase of instructional change will provide a more complete picture of the factors enabling or hindering sustained adoption.

Second, students' perception of RBIS implementation warrants further exploration. While this study primarily examined instructors' decision-making processes, understanding how students experience and respond to RBIS strategies will offer critical insights into its effectiveness. Future research will analyze student feedback, engagement levels, and learning outcomes in the same university to assess the impact of RBIS on student learning in mathematically intensive physics courses.

Future research should explore how RBIS adoption evolves over time, particularly how systemic policies, contextual departmental dynamics, and environmental factors interact to shape sustained instructional change.

ACKNOWLEDGMENTS

We extend our sincere appreciation to Dr. Christine Lindström for her invaluable support and encouragement throughout the development of this project. The authors gratefully acknowledge the generous support of the Indonesia Endowment Fund for Education (*Lembaga Pengelola Dana Pendidikan*), which made this research possible. This work was additionally supported by the University of Colorado Boulder's Center for STEM Learning, and the publication of this article was funded by the University of Colorado Boulder Libraries Open Access Fund.

DATA AVAILABILITY

The data that support the findings of this article are not publicly available because they contain sensitive personal information. The data are available from the authors upon reasonable request.

APPENDIX: INTERVIEW QUESTIONS

1. Introduction

- *Settling down.*
- *Acknowledgment of traditional owners of the land.*
- *Introducing the purpose of the interview and asking interviewee's time availability.*

2. Main sections

a. Preparation of the course

- Can you tell me about the *Quantum Physics/Classical Mechanics and Special Relativity/Electromagnetism*

course? For instance, when did you start teaching it? What did it look like, and what changes did you make over time? *Possible follow-up questions:*

1. How long have you been teaching the course?
 2. How does it evolve throughout the years (*mention if necessary*: the 3+ system and shifting in and out of the COVID-19 pandemic mode)?
 3. Do you know why you were put on the course?
 4. How did you approach the course in the first place?
 5. What did you inherit from the previous course convenor?
 6. How long did it take to prepare all the components of the course in general?
 7. Considering an instructor's responsibilities, how did you manage your time against all other responsibilities and demands of your time?
 8. How was your experience the first time you taught the course?
 9. What data/feedback/evidence did you use to evaluate the course after the first year of teaching?
 10. What changes (if any) did you make to improve the course in the following years?
 11. How is the implementation of the changes?
- Can you tell me about the specific approaches to teaching you take in your course? *Possible follow-up questions:*
 1. What makes these methods interesting?
 2. Did you use it?
 3. Why did you decide to use/not use it?
 4. How did you get support in designing the course using these teaching methods?
 5. If you did not get support, did you feel that you could be benefited from additional support?
 - Have you heard about Research-Based Instructional Strategies (RBIS) or also known as active learning? *Possible follow-up questions:*
 1. Where did you learn about it?
 2. If you haven't heard about, do you have any interest to learn about it?
 3. If you do, why do you want to learn about it, otherwise why don't you want to learn about it?
 4. If you heard about it, did you use it in teaching?
 5. How did you get support in designing the course using research-based instructional strategies?

b. Experiences in implementing the designed method

- How was the implementation of the designed methods?
- I found that the co-teaching format is interesting. Can you explain to me why the course is conducted that way? *Possible follow-up question:*
 1. How was your experience teaching the course using the format?

- What challenges did you experience in implementing the designed methods? *Possible follow-up questions:*
 1. How did you deal with the challenges?
 2. What factors supported the implementation of your design?
- How did you ensure that students received support for their learning?

c. Reflection of the methods

- Would you consider the course to have gone according to plan this year? *Possible follow-up questions:*
 1. Do you feel you were able to achieve the goal of the course this year?
 2. In your opinion, what makes it successful (or not)?
 3. What lessons have you learned from doing the course for several years?
 4. How did the use of research-based instructional strategies impact your overall workload as an instructor?

d. Future improvement and sustainability

- Considering the experience you had in conducting the course this year, what did you improve compared to previous years? *Possible follow up questions:*
 1. Why was that improvement relevant to your course?
 2. Do you think your experience and effort in making improvements uphold the values and principles of the school and the university? Please elaborate.
 3. Do you think you want to sustain the effort to make improvement? Please explain the reasoning.

3. Closing

Expressing thankfulness for agreeing to participate in the interview and responding to questions the participants might have related to the research study

-
- [1] T. C. Andrews and P. P. Lemons, It's personal: Biology instructors prioritize personal evidence over empirical evidence in teaching decisions, *CBE Life Sci. Educ.* **14**, ar7 (2015).
 - [2] N. S. Bidabadi, A. N. Isfahani, A. Rouhollahi, and R. Khalili, Effective teaching methods in higher education: Requirements and barriers, *J. Adv. Med. Educ. Prof.* **4**, 170 (2016), <https://pmc.ncbi.nlm.nih.gov/articles/PMC5065908/>.
 - [3] L. E. Strubbe, A. M. Madsen, S. B. McKagan, and E. C. Sayre, Beyond teaching methods: Highlighting physics faculty's strengths and agency, *Phys. Rev. Phys. Educ. Res.* **16**, 020105 (2020).
 - [4] M. Dancy, C. Henderson, N. Apkarian, E. Johnson, M. Stains, J. R. Raker, and A. Lau, Physics instructors' knowledge and use of active learning has increased over the last decade but most still lecture too much, *Phys. Rev. Phys. Educ. Res.* **20**, 010119 (2024).
 - [5] M. E. Bathgate, O. R. Aragón, A. J. Cavanagh, J. Frederick, and M. J. Graham, Supports: A key factor in faculty implementation of evidence-based teaching, *CBE Life Sci. Educ.* **18**, ar22 (2019).
 - [6] S. Freeman, S. L. Eddy, M. McDonough, M. K. Smith, N. Okoroafor, H. Jordt, and M. P. Wenderoth, Active learning increases student performance in science, engineering, and mathematics, *Proc. Natl. Acad. Sci. U.S.A.* **111**, 8410 (2014).
 - [7] C. Henderson, A. Beach, and N. Finkelstein, Facilitating change in undergraduate STEM instructional practices: An analytic review of the literature, *J. Res. Sci. Teach.* **48**, 952 (2011).
 - [8] C. H. Crouch and E. Mazur, Peer instruction: Ten years of experience and results, *Am. J. Phys.* **69**, 970 (2001).
 - [9] M. Prince, Does active learning work? A review of the research, *J. Eng. Educ.* **93**, 223 (2004).
 - [10] M. Prince, M. Borrego, C. Henderson, S. Cutler, and J. Froyd, Use of research-based instructional strategies in core chemical engineering courses, *Chem. Eng. Educ.* **47**, 27 (2013), <https://journals.flvc.org/cee/article/view/118512>.
 - [11] E. J. Theobald, M. J. Hill, E. Tran, S. Agrawal, E. N. Arroyo, S. Behling, N. Chambwe, D. L. Cintrón, J. D. Cooper, G. Dunster *et al.*, Active learning narrows achievement gaps for underrepresented students in undergraduate science, technology, engineering, and math, *Proc. Natl. Acad. Sci. U.S.A.* **117**, 6476 (2020).
 - [12] C. Henderson, M. Dancy, and M. Niewiadomska-Bugaj, Use of research-based instructional strategies in introductory physics: Where do faculty leave the innovation-decision process?, *Phys. Rev. ST Phys. Educ. Res.* **8**, 020104 (2012).
 - [13] M. H. Dancy, C. Turpen, and C. Henderson, Why do faculty try research based instructional strategies?, *AIP Conf. Proc.* **1289**, 117 (2010).
 - [14] M. Dancy, C. Henderson, and C. Turpen, How faculty learn about and implement research-based instructional strategies: The case of peer instruction, *Phys. Rev. Phys. Educ. Res.* **12**, 010110 (2016).
 - [15] S. Tobias, From innovation to change: Forging a physics education reform agenda for the 21st century, *J. Sci. Educ. Technol.* **9**, 1 (2000).
 - [16] C. Henderson and M. H. Dancy, Impact of physics education research on the teaching of introductory quantitative

- physics in the United States, *Phys. Rev. ST Phys. Educ. Res.* **5**, 020107 (2009).
- [17] M.H. Dancy and C. Henderson, Experiences of new faculty implementing research-based instructional strategies, *AIP Conf. Proc.* **1413**, 163 (2012).
- [18] C. Henderson and M.H. Dancy, Barriers to the use of research-based instructional strategies: The influence of both individual and situational characteristics, *Phys. Rev. ST Phys. Educ. Res.* **3**, 020102 (2007).
- [19] S.E. Brownell and K.D. Tanner, Barriers to faculty pedagogical change: Lack of training, time, incentives, and tensions with professional identity?, *CBE Life Sci. Educ.* **11**, 339 (2012).
- [20] O.R. Aragón, S.L. Eddy, and M.J. Graham, Faculty beliefs about intelligence are related to the adoption of active-learning practices, *CBE Life Sci. Educ.* **17**, ar47 (2018).
- [21] C. Henderson and M.H. Dancy, Teaching, learning and physics education research: Views of mainstream physics professors, *AIP Conf. Proc.* **790**, 109 (2005).
- [22] C. Turpen and N.D. Finkelstein, The construction of different classroom norms during peer instruction: Students perceive differences, *Phys. Rev. ST Phys. Educ. Res.* **6**, 020123 (2010).
- [23] S.E. Bradforth, E.R. Miller, W.R. Dichtel, A.K. Leibovich, A.L. Feig, J.D. Martin, K.S. Bjorkman, Z.D. Schultz, and T.L. Smith, University learning: Improve undergraduate science education, *Nature (London)* **523**, 282 (2015).
- [24] A.C. Lau, C. Henderson, M. Stains, M. Dancy, C. Merino, N. Apkarian, J.R. Raker, and E. Johnson, Characteristics of departments with high-use of active learning in introductory STEM courses: Implications for departmental transformation, *Int. J. STEM Educ.* **11**, 10 (2024).
- [25] C. Wieman, *Improving How Universities Teach Science: Lessons from the Science Education Initiative* (Harvard University Press, Cambridge, MA, 2017).
- [26] N. Budini, L. Marino, R. Carreri, C. Cámara, and S. Giorgi, Perceptions of students after implementing peer instruction in an introductory physics course, *Smart Learn. Environ.* **6**, 1 (2019).
- [27] M. Good, A. Maries, and C. Singh, Impact of traditional or evidence-based active-engagement instruction on introductory female and male students' attitudes and approaches to physics problem solving, *Phys. Rev. Phys. Educ. Res.* **15**, 020129 (2019).
- [28] D. Knudson and B. Wallace, Student perceptions of low-tech active learning and mastery of introductory biomechanics concepts, *Sports Biomech.* **20**, 1 (2021).
- [29] N. Apkarian, C. Henderson, M. Stains, J. Raker, E. Johnson, and M. Dancy, What really impacts the use of active learning in undergraduate STEM education? Results from a national survey of chemistry, mathematics, and physics instructors, *PLoS One* **16**, e0247544 (2021).
- [30] C. Henderson, A. Beach, and M. Famiano, Promoting instructional change via co-teaching, *Am. J. Phys.* **77**, 274 (2009).
- [31] S. Chasteen, K. Perkins, P. Beale, S. Pollock, and C. Wieman, A thoughtful approach to instruction: Course transformation for the rest of us, *J. Coll. Sci. Teach.* **40**, 24 (2011), https://www.academia.edu/download/84147700/A_Thoughtful_Approach_to_Instruction_Cou20220414-1-cv46yf.pdf.
- [32] O. Aragón and M. Graham, *Census Survey Report for the Summer Institutes on Scientific Teaching* (National Academies of Science, Washington, DC, 2015).
- [33] R.K. Yin, *Case Study Research: Design and Methods* (Sage, Thousand Oaks, CA, 2009), Vol. 5.
- [34] R. Longhurst, Semi-structured interviews and focus groups, in *Key Methods in Geography* (SAGE Publications, London, UK, 2003), Vol. 3, p. 143.
- [35] W.C. Adams, Conducting semi-structured interviews, in *Handbook of Practical Program Evaluation* (Jossey-Bass, San Francisco, CA, 2015), p. 492.
- [36] V. Braun and V. Clarke, One size fits all? What counts as quality practice in (reflexive) thematic analysis?, *Qual. Res. Psychol.* **18**, 328 (2021).
- [37] V. Braun and V. Clarke, *Thematic Analysis* (American Psychological Association, Washington, DC, 2012).
- [38] N. Finkelstein, A.F. Greenhoot, G. Weaver, and A.E. Austin, A department-level cultural change project: Transforming evaluation of teaching, in *Transforming Institutions: Accelerating Systemic Change in Higher Education* (Pressbooks, 2020), Vol. 27.
- [39] M.L. McHugh, Interrater reliability: The kappa statistic, *Biochem. Med.* **22**, 276 (2012).
- [40] M. Dancy and C. Henderson, Pedagogical practices and instructional change of physics faculty, *Am. J. Phys.* **78**, 1056 (2010).
- [41] H. Georgiou, M. Sharma, and A. Ling, Peer review of teaching: What features matter? A case study within stem faculties, *Innov. Educ. Teach. Int.* **55**, 190 (2018).
- [42] M.F. Durham, O.R. Aragón, M.E. Bathgate, A. Bobrownicki, A.J. Cavanagh, X. Chen, W.M. Trochim, J.K. Waterhouse, M.J. Graham, and B.A. Couch, Benefits of a college STEM faculty development initiative: Instructors report increased and sustained implementation of research-based instructional strategies, *J. Microbiol. Biol. Educ.* **21**, 21 (2020).
- [43] A. Diery, F. Vogel, M. Knogler, and T. Seidel, Evidence-based practice in higher education: Teacher educators' attitudes, challenges, and uses, in *Frontiers in Education* (Frontiers Media SA, Lausanne, Switzerland, 2020), Vol. 5, p. 62.
- [44] T.J. Lund and M. Stains, The importance of context: An exploration of factors influencing the adoption of student-centered teaching among chemistry, biology, and physics faculty, *Int. J. STEM Educ.* **2**, 1 (2015).
- [45] M.C. Wright, I. Bergom, and T. Bartholomew, Decreased class size, increased active learning? Intended and enacted teaching strategies in smaller classes, *Active Learn. Higher Educ.* **20**, 51 (2019).
- [46] C. Turpen, M. Dancy, and C. Henderson, Perceived affordances and constraints regarding instructors' use of peer instruction: Implications for promoting instructional change, *Phys. Rev. Phys. Educ. Res.* **12**, 010116 (2016).
- [47] P.J. White, I. Larson, K. Styles, E. Yuriev, D.R. Evans, P. Rangachari, J.L. Short, B. Exintaris, D.T. Malone, B. Davie *et al.*, Adopting an active learning approach to teaching in a research-intensive higher education context

- transformed staff teaching attitudes and behaviours, *Higher Educ. Res. Dev.* **35**, 619 (2016).
- [48] M. H. Dancy and C. Henderson, Beyond the individual instructor: Systemic constraints in the implementation of research-informed practices, *AIP Conf. Proc.* **790**, 113 (2005).
- [49] K. VanWyngaarden, J. A. Pelton, P. M. Oquendo, and C. Moore, High-impact teaching practices in higher education: Understanding barriers, concerns, and obstacles to their adoption, *Trends Higher Educ.* **3**, 105 (2024).
- [50] M. T. Hora, Organizational factors and instructional decision-making: A cognitive perspective, *Rev. High. Educ.* **(35)**, 207 (2012).
- [51] S. E. Shadle, A. Marker, and B. Earl, Faculty drivers and barriers: Laying the groundwork for undergraduate STEM education reform in academic departments, *Int. J. STEM Educ.* **4**, 1 (2017).
- [52] G. Hampton, C. Rhodes, and M. Stokes, *A Practical Guide to Mentoring, Coaching and Peer-Networking: Teacher Professional Development in Schools and Colleges* (Routledge, London, UK, 2004).
- [53] T. More, F. Goldberg, M. Basir, S. Maier, and E. Price, From implementation to reflection: Exploring faculty experiences in a curriculum-focused FOLC through multi-case analysis, *Discip. Interdiscip. Sci. Educ. Res.* **6**, 7 (2024).
- [54] S. Aslan, Investigating the relation between educational philosophies adopted by prospective teachers and their teaching-learning conceptions, *Pegem J. Educ. Instr.* **8**, 307 (2018).
- [55] J. M. Cruz-Bohorquez, S. G. Adams, and F. A. Bravo, The academic system influence on instructional change: A conceptual systems dynamics model of faculty motivation to adopt research-based instructional strategies (RBIS), *Educ. Sci.* **14**, 544 (2024).
- [56] J. Michael, Faculty perceptions about barriers to active learning, *Coll. Teach.* **55**, 42 (2007).
- [57] M. E. Bathgate, O. R. Aragón, A. J. Cavanagh, J. K. Waterhouse, J. Frederick, and M. J. Graham, Perceived supports and evidence-based teaching in college stem, *Int. J. STEM Educ.* **6**, 1 (2019).
- [58] J. J. Walczyk, L. L. Ramsey, and P. Zha, Obstacles to instructional innovation according to college science and mathematics faculty, *J. Res. Sci. Teach.* **44**, 85 (2007).
- [59] B. Craig and J. L. Hsu, A multi-year longitudinal study exploring the impact of the COVID-19 pandemic on students' familiarity and perceptions of active learning, *Active Learn. Higher Educ.* **26**, 177 (2024).
- [60] A. Maldonado-Trapp and C. Bruna, The evolution of active learning in response to the pandemic: The role of technology, in *The COVID-19 Aftermath: Volume II: Lessons Learned* (2024), p. 247, [10.1007/978-3-031-61943-4](https://doi.org/10.1007/978-3-031-61943-4).
- [61] J. Ametepe and N. Khan, Teaching physics during COVID-19 pandemic: Implementation and report of teaching strategies to support student learning, *Phys. Educ.* **56**, 065030 (2021).
- [62] A. Corrales, F. Goldberg, E. Price, and C. Turpen, Faculty persistence with research-based instructional strategies: A case study of participation in a faculty online learning community, *Int. J. STEM Educ.* **7**, 1 (2020).
- [63] A. M. Pallas, A. Neumann, and C. M. Campbell, *Policies and Practices to Support Undergraduate Teaching Improvement* (American Academy of Arts and Sciences, Cambridge, MA, 2017).
- [64] J. C. Corbo, D. L. Reinholz, M. H. Dancy, S. Deetz, and N. Finkelstein, Framework for transforming departmental culture to support educational innovation, *Phys. Rev. Phys. Educ. Res.* **12**, 010113 (2016).
- [65] A. F. Greenhoot, C. Aslan, S. Chasteen, W. Code, and S. B. Sherman, Variations on embedded expert models: Implementing change initiatives that support departments from within, in *Transforming Institutions: Accelerating Systemic Change in Higher Education*, edited by K. White, A. Beach, N. Finkelstein, C. Henderson, S. Simkins, L. Slakey, M. Stains, G. Weaver, and L. Whitehead (Pressbooks, 2020), <http://openbooks.library.umass.edu/ascnti2020/>.
- [66] C. Pfund, S. Miller, K. Brenner, P. Bruns, A. Chang, D. Ebert-May, A. P. Fagen, J. Gentile, S. Gossens, I. M. Khan *et al.*, Summer institute to improve university science teaching, *Science* **324**, 470 (2009).