

Co-teaching in Undergraduate STEM Education: A Lever for Pedagogical Change toward Evidence-Based Teaching?

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ABSTRACT

Could co-teaching be a mechanism to support the adoption of evidence-based teaching strategies? Co-teaching has been proposed as a lever for fostering pedagogical change and has key attributes of a successful change strategy, but does research indicate co-teaching effectively shifts instructional practices? Based on our review of the emerging evidence, we wrote this essay for multiple audiences, including science, technology, engineering, and mathematics (STEM) instructors, education development professionals, leaders who oversee teaching, and researchers. We define co-teaching in the context of STEM higher education and summarize what is known about the pedagogical changes that co-teaching could support and the potential mechanisms behind these changes. We share recommendations based on the available evidence for those who need productive ideas right now. We also lay out a variety of future directions for research about co-teaching as a lever for pedagogical change. Achieving widespread and impactful pedagogical change is a monumental undertaking facing STEM higher education, and multiple approaches will be needed to meet this challenge. Co-teaching has potential to shift ways of thinking and pedagogical practices among undergraduate STEM faculty, but how co-teaching is enacted is likely crucial to its impact, as is the context in which it occurs.

INTRODUCTION

When have you experienced two instructors teaching in the same learning environment? Were you a student appreciating the value of the perspective each instructor presented, or perhaps struggling to adapt to their different teaching approaches? Were you one of the instructors navigating the dynamics of the classroom with your colleague? Perhaps you were a leader who encouraged this practice in your unit? Whether you were a student, instructor, or leader in this recollection, how do you imagine that teaching together influenced the practices and thinking of the instructors?

Co-teaching has been used as a pedagogical development strategy in multiple settings, including training programs for physicians, social workers, and teachers (e.g., Orlander *et al.*, 2000; Crow and Smith, 2005; Bacharach *et al.*, 2008). While teaching together is a common arrangement in university and college science, technology, engineering, and mathematics (STEM) courses, the impacts of this structure on instructor teaching practices remain poorly understood. Coming from varied academic roles, we were intrigued by studies that show the potential of co-teaching as a lever for pedagogical change toward evidence-based teaching (e.g., Beach *et al.*, 2008; Henderson *et al.*, 2009; Bailey and Nagamine, 2012; Stang and Strubbe, 2015; Holland *et al.*, 2018; Scherer *et al.*, 2020). Co-teaching aligns with key attributes of successful change strategies: It lasts an academic term or more, has the potential to change beliefs, and is an

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TABLE 1. Potential benefits of reading this paper for different audiences

Who might benefit?	What might you learn and what sections might you prioritize?
Instructors new to or considering co-teaching	Learn about the practice of co-teaching and ideas for getting started (see Table 2)
Instructors with co-teaching experience	Dig into the research basis for the practice and make modifications based on suggestions from the literature (see Table 2 and <i>Future Directions for Research on Co-teaching for Pedagogical Change</i>)
Educational developers who support instructors	Identify practices to support faculty in co-teaching arrangements and consider opportunities to use co-teaching in pedagogical development efforts (see Table 2, Table 3, and <i>Future Directions for Research on Co-teaching for Pedagogical Change</i>)
Departmental leaders who make teaching assignments	Consider whether investing in co-teaching is likely to result in pedagogical change given the available resources and practices within the department (see Table 3 and <i>How Does a Teaching Evaluation System Impact Co-teaching as a Lever for Pedagogical Change?</i>)
Education researchers	Consider gaps in the literature where the community might learn more about co-teaching and how it could contribute to pedagogical change (see <i>Future Directions for Research on Co-teaching for Pedagogical Change</i>)

existing practice within university systems (Henderson *et al.*, 2011). Given the need to improve student retention and learning outcomes in STEM higher education (President's Council of Advisors on Science and Technology, 2012; Seymour *et al.*, 2019), could the STEM higher education community leverage co-teaching to expand the use of evidence-based teaching? The goal of this essay is to summarize existing literature about co-teaching in undergraduate STEM education and propose questions for future work that examines the potential of co-teaching for achieving widespread and meaningful change in teacher and student outcomes. We imagine that multiple audiences can find value in considering co-teaching for pedagogical change (Table 1).

The term “co-teaching” is used in multiple ways, and there are several terms to describe this kind of teaching, such as collaborative teaching, team teaching, partnered teaching, and paired teaching. In this paper, we define co-teaching as a collaborative endeavor between two or more instructors in the same discipline who fully participate in all elements of the teaching, including course design; instruction; and assessment before, during, and after the course. Instructors who teach one after the other in the same course with minimal collaborative decision making are not included in this definition. Though STEM departments in research-intensive universities often assign more than one teacher to a course, these arrangements are not likely to advance evidence-based teaching unless the department expects and supports faculty to collaborate closely. This paper does not examine co-teaching arrangements in which instructors are tasked with bringing expertise from different disciplines (e.g., philosophy and biology) to the same course, often called “interdisciplinary co-teaching.” *How* co-teaching occurs and *who* is involved may have a tremendous impact on its potential as a lever for change, and our definition is based on researchers' current understanding of these critical components. With that in mind, this definition should be elaborated on and refined over time as research generates more insights about co-teaching.

Guided by this definition of co-teaching, we conducted a literature search focusing on the college and university setting. This search primarily identified small-scale and case study research. By searching Google Scholar, we identified 13 essays and research studies that aligned with our definition of co-teaching and that occurred in the context of STEM higher education

(see full list in Supplemental Material). The majority of research studies investigated co-teaching over a short time frame (e.g., a semester or two) and studied one or a few co-teaching pairs. Many of these studies focused on teaching arrangements consisting of expert and novice instructor pairings, the implications of which are discussed later in this essay. Only a handful of studies examined instructional practices among one or both members of co-teaching pairs (Beach *et al.*, 2008; Henderson *et al.*, 2009; Bailey and Nagamine, 2012; Holland *et al.*, 2018; Strubbe *et al.*, 2019), and only two collected data about student learning or perceptions (Bailey and Nagamine, 2012; Metzger, 2015). Despite the limitations of the available literature, we can draw on this work to generate hypotheses about the potential impact and mechanism of co-teaching and identify areas ripe for further research. We can also rely on this scholarship to make tentative recommendations for those who need ideas about productive co-teaching right now.

CURRENT EVIDENCE ABOUT THE IMPACT OF CO-TEACHING ON PEDAGOGICAL CHANGE

What Pedagogical Changes Might Result from Participation in Co-teaching?

Studies have thus far reported some possible positive outcomes of co-teaching for pedagogical change. Co-teaching may support instructors in:

- 1. Adopting an interactive approach to teaching immediately.** This occurred in cases when the co-teaching arrangement paired an instructor new to teaching and an instructor with expertise regarding evidence-based instructional strategies (e.g., Beach *et al.*, 2008; Henderson *et al.*, 2009; Bailey and Nagamine, 2012). However, the longevity of change remains unclear: Stang and Strubbe (2015) report persistence of evidence-based teaching in the academic term after co-teaching, whereas in another case, an instructor dropped some evidence-based practices after co-teaching as a strategy to reduce workload (Beach *et al.*, 2008; Henderson *et al.*, 2009).
- 2. Developing a critically reflective teaching practice.** Co-teaching has the potential to accelerate teaching improvement (Orlander *et al.*, 2000; Henderson *et al.*, 2009). This may occur as a result of instructors developing a habit of critical reflection about their teaching, especially

when this is integral to the co-teaching experience (e.g., Orlander *et al.*, 2000). It may also occur by fostering interest in teaching and learning research as a means of informing one's teaching practice (Stang and Strubbe, 2015).

3. **Developing teaching knowledge.** The co-teaching experience can help instructors develop knowledge about how students learn, how to implement interactive pedagogical strategies, how to manage the classroom, and how to facilitate particular types of interactive lessons (Bailey and Nagamine, 2012; Scherer *et al.*, 2020). The development of this knowledge may depend on an expert co-teacher being able to clearly articulate the justifications for particular classroom practices (Scherer *et al.*, 2020).
4. **Shifting instructors' thinking about students and teaching.** Perceptions of positive student responses to interactive lessons and other evidence-based practices may increase instructor confidence with new pedagogical approaches, especially when these observations counter a novice instructor's initial expectations (Beach *et al.*, 2008; Henderson *et al.*, 2009; Strubbe *et al.*, 2019). Such student responses may include increased attendance, better engagement, positive survey feedback, and productive interactions with students (Beach *et al.*, 2008; Henderson *et al.*, 2009; Bailey and Nagamine, 2012). Instructors may also discover that they enjoy teaching using interactive and evidence-based pedagogies more than conducting traditional, lecture-dominated classes (Bailey and Nagamine, 2012).

What Mechanisms of Co-teaching Might Contribute to Pedagogical Change?

If co-teaching is to be used to support pedagogical change, we need to understand the details of how co-teaching could support changes in instructor thinking and teaching practices. The current literature base cannot yet fully answer these questions, but one model that has guided prior work offers a useful starting place. The primary way in which co-teaching in higher education has been investigated is within the cognitive apprenticeship model (Beach *et al.*, 2008; Henderson *et al.*, 2009; Stang and Strubbe, 2015; Cordie *et al.*, 2020). Cognitive apprenticeship entails a partnership between an expert and novice, which aims to make expert thinking and problem-solving approaches explicit and involves modeling of expert strategies (Collins *et al.*, 1991). Cognitive apprenticeship emphasizes active coaching or mentoring from the expert, opportunities for both the expert and novice to articulate and discuss their thinking and problem-solving strategies, as well as active reflection and engagement in an authentic task (Collins *et al.*, 1991). There may be other theoretical frameworks that provide useful lenses for considering co-teaching as a lever for pedagogical change. We focus here on cognitive apprenticeship, because that is the model that has grounded prior studies of co-teaching.

Co-teaching through the cognitive apprenticeship model may be useful for fostering pedagogical change, because learning about teaching is paired with guided practice in an authentic context. As a result, novice instructors may be learning from an expert instructor about evidence-based strategies, observing those strategies in use, and implementing those strategies in their own teaching. Because teaching expertise is often tacit and learned in context (e.g., Alonzo and Kim, 2016; Carlson *et al.*, 2019), the cognitive apprenticeship model may help

instructors make unspoken ideas or strategies explicit. This may be bolstered by individual and collaborative reflection with a co-teacher, potentially promoting metacognition about teaching and construction of pedagogical knowledge that might not develop in a solitary teaching experience. Indeed, effective coaching (achieved through training, productive attitudes, and cooperative relationships) may be one of the most important conditions for co-teaching to successfully engender pedagogical change (Stang and Strubbe, 2015; Cordie *et al.*, 2020).

While the cognitive apprenticeship model has been used as the main theoretical grounding for co-teaching as a mechanism of pedagogical change, the model is limited by framing a co-teaching relationship as an apprenticeship with one instructor as a mentor and the other as a mentee. But in some instances, instructors indicated that a coequal and collegial partnership was critical to the success of their learning in a co-teaching relationship (Beach *et al.*, 2008; Henderson *et al.*, 2009; Morelock *et al.*, 2017). With this in mind, some studies have recommended that co-teaching be framed as a reciprocal learning opportunity, even within a mentor–mentee relationship. For example, expert instructors can gain new perspectives and strategies from their collaborators, who have differing life and teaching experiences (Henderson *et al.*, 2009; Morelock *et al.*, 2017; Holland *et al.*, 2018; Strubbe *et al.*, 2019; Cordie *et al.*, 2020).

Recommendations for Co-teaching That Could Help Support Pedagogical Change

In Tables 2 and 3, we summarize recommendations from existing literature. We offer these as the best recommendations that can currently be made, and in exploring them, we encourage readers to reflect on their own practice or support of co-teaching. We also urge readers to consider these recommendations as subject to change with additional research. Instructors can read recommendations about engaging in co-teaching in Table 2. Educational developers may find Tables 2 and 3 useful in their work to support and advise instructors and departmental leaders. Departmental leaders can read recommendations about supporting co-teaching in Table 3 and find an elaborated list for departments in Strubbe *et al.* (2019). See the Supplemental Table for an alternative arrangement of Tables 2 and 3 that includes a summary of findings from each study.

FUTURE DIRECTIONS FOR RESEARCH ON CO-TEACHING FOR PEDAGOGICAL CHANGE

To better understand whether and how to employ co-teaching as part of a multifaceted approach to achieving widespread pedagogical change in STEM higher education, education researchers can investigate the features, participants, and conditions that could enable co-teaching to effectively shift teaching practices. This aligns with the construct of fidelity of implementation (e.g., Stains and Vickrey, 2017; Offerdahl *et al.*, 2018), which refers to the extent to which critical components of a practice are present when the practice is enacted (e.g., Stains and Vickrey, 2017). Research can help determine the critical components of co-teaching that contribute to pedagogical change toward evidence-based teaching. It may be the case that co-teaching can vary considerably and still reliably shift ways of thinking and instructional practices among co-teachers. Alternatively, investigators may determine that a specific set of features

TABLE 2. Recommendations about enacting co-teaching

Throughout a co-teaching partnership:

- Develop collegial and cooperative working relationships^{b, c, d, e, i, j, k, l}
- Engage in regular communication and close collaboration^{a, c, d, e, f, g, h, i, k, l}
- Consider and address differences in power dynamics and instructor identities^{c, d, e, f, h, i, l}
- Meet early and often^{a, c, d, e}

Before the term:

- Discuss what you hope to gain from co-teaching^{c, h, i, k, l}
- Discuss your guiding teaching philosophies, most important goals as a teacher, approaches to teaching, and reasons for using those approaches^{c, d, f, h, j, k}
- Collaborate to develop course structure and content, including objectives, activities, assignments, grading, norms, and expectations^{a, c, d, f, g, h, i, j}

During the term:

- Both instructors attend and facilitate class each day^{a, c, d, f, g, h, l}
- Clarify expectations to students (such as which co-teacher to contact for certain questions, etc.)^{c, e, f, g, j}
- Present as an equal-status team to students (e.g., explicitly introduce instructors as equal partners on the first day)^{c, d, e, f, l}
- Debrief and reflect regularly and constructively, aimed at: improving collaboration, improving student learning, and supporting pedagogical goals of the partnership^{a, b, c, d, e, f, l, j, k, l}

References: ^aBailey and Nagamine, 2012; ^bBeach *et al.*, 2008; ^cCordie *et al.*, 2020; ^dHolland *et al.*, 2018; ^eJarvis and Kariuki, 2017; ^fMeizlish and Anderson, 2018; ^gMetzger, 2015; ^hMorelock *et al.*, 2017; ⁱOrlander *et al.*, 2000; ^jScherer *et al.*, 2020; ^kStang and Strubbe, 2015; ^lStrubbe *et al.*, 2019.

or contexts are necessary to achieve pedagogical change or that co-teaching arrangements may be ineffective or even detrimental under certain circumstances. We encourage researchers to draw on theories related to learning in context to identify a suite of co-teaching features likely to be important. These might include the cognitive apprenticeship model (e.g., Collins *et al.*, 1991; Beach *et al.*, 2008; Henderson *et al.*, 2009), the cognitive reconstruction of knowledge model (e.g., Dole and Sinatra, 1998; Bailey and Nagamine, 2012), or other frameworks relevant to co-teaching that have not yet been explored. Features hypothesized to be important based on theory must then be tested to determine the impact of a specific co-teaching approach on pedagogical change across co-teaching pairs and contexts.

With these ideas in mind, we first propose research questions that build on prior work and that, once explored further, would allow researchers and practitioners to better plan and use co-teaching for pedagogical change toward evidence-based teaching (Table 4). We also describe research design considerations for future research projects.

Can Co-teaching Change Instructor Thinking?

Co-teaching may support changes to individual instructor's thinking, which could impact their teaching immediately and in the future. Drawing on prior studies of co-teaching and other relevant research, we propose that co-teaching could support the development of important teaching knowledge, alter instructor's expectations about undergraduate teaching and

learning, and promote the development of self-reflective teachers (e.g., Orlander *et al.*, 2000; Henderson *et al.*, 2009; Bailey and Nagamine, 2012; Scherer *et al.*, 2020). These hypotheses need to be tested in new contexts and with larger numbers of co-teaching pairs.

Teaching Knowledge. Co-teaching likely influences teaching knowledge, including pedagogical content knowledge and pedagogical knowledge, but the existing research has not yet examined how co-teaching influences these key areas of teaching expertise. Pedagogical content knowledge is topic-specific knowledge about teaching and learning, such as awareness of common student thinking and difficulties associated with learning a specific topic (e.g., natural selection, central dogma) and knowledge of cases, examples, analogies, and tasks that help students develop their understanding of the topic (e.g., Park and Oliver, 2008). Research across disciplines and educational levels demonstrates that this knowledge is a critical component of evidence-based teaching. Specifically, this knowledge helps instructors design and effectively implement lessons that target the difficulties students encounter when learning a topic and more efficiently understand and respond to student thinking while teaching (e.g., Wagner *et al.*, 2007; Speer and Wagner, 2009; Park and Chen, 2012; Johnson and Larsen, 2012; Auerbach *et al.*, 2018; Andrews *et al.* 2019, 2022; Gehrtz *et al.*, 2022). Pedagogical knowledge is knowledge of teaching that is generalizable

TABLE 3. Recommendations about supporting co-teaching

- Match recognition with time spent (co-teaching does not halve an instructor's time investment relative to solo teaching)^{d, e, h, j, l}
- Consider how evaluation structures can be changed to better or more directly assess co-teaching (e.g., opening up standardized end-of-term evaluations to instructors' additional custom questions)^f
- Provide or connect instructors with training and support for co-teaching^{k, l}
- Select faculty who share a goal of developing as instructors^{a, b, c, h, j, k, l}
- Select expert co-teachers based on demonstrated commitment to and experience with evidence-based teaching^{a, b, c, j, l}
- Select expert co-teachers familiar with effective mentorship strategies, or connect expert co-teachers with mentorship training^{b, c, d, j, k, l}
- Consider allocation of resources that allows instructors to devote time to the teaching development process (e.g., select established courses with pre-existing learning materials, assign a teaching assistant to support the course)^{a, b, j, k, l}

References: ^aBailey and Nagamine, 2012; ^bBeach *et al.*, 2008; ^cCordie *et al.*, 2020; ^dHolland *et al.*, 2018; ^eJarvis and Kariuki, 2017; ^fMeizlish and Anderson, 2018; ^gMetzger, 2015; ^hMorelock *et al.*, 2017; ⁱOrlander *et al.*, 2000; ^jScherer *et al.*, 2020; ^kStang and Strubbe, 2015; ^lStrubbe *et al.*, 2019.

TABLE 4. Open research questions for future investigations of co-teaching.

Can co-teaching change instructor thinking? <i>Such as by...</i>
<ul style="list-style-type: none"> • Facilitating the development of pedagogical content knowledge and pedagogical knowledge • Creating new expectations about what is possible and effective in college classrooms • Fostering a habit of critical teaching self-reflection
What features of co-teaching experiences lead to pedagogical change? <i>Such as...</i>
<ul style="list-style-type: none"> • Collaborative goal setting, planning, classroom interactions, and debriefing • Co-teaching with established materials and/or an established classroom climate • Co-teacher expertise, including evidence-based teaching training and experience • Repeated opportunities to co-teach
How does a teaching evaluation system impact co-teaching as a lever for change? <i>Such as by..</i>
<ul style="list-style-type: none"> • Using evaluation practices that recognize effective evidence-based teaching • Recognizing that co-teaching itself might impact student evaluations of instructors

across topics, such as knowledge of how people learn, how to monitor student thinking, how to foster an inclusive and equitable classroom, and how to motivate students (Auerbach and Andrews, 2018). This knowledge base has been less extensively studied, but some research suggests it facilitates effective evidence-based teaching (Andrews *et al.*, 2022). For example, pedagogical knowledge allows instructors to design and effectively implement lessons that challenge students to develop and articulate their reasoning and that actively monitor and respond to student thinking in real time (Auerbach *et al.*, 2018; Andrews *et al.*, 2019; Waugh and Andrews, 2020).

Co-teaching may be uniquely suited to help faculty develop both of these important knowledge bases, because co-instructors hold in-depth conversations to share their rationales for specific instructional practices (e.g., Scherer *et al.*, 2020). Co-teaching may create rare opportunities for faculty to hear and respond to one another's reasoning in the authentic context of their own teaching responsibilities, which could be conditions that foster deep learning (e.g., Chi and Wylie, 2014). Additionally, unlike many professional development programs, co-teaching can involve collaborative work and problem-solving between two or more people working with the same students, about the same content and skills, and in the same instructional setting.

Instructor Expectations. Co-teaching may create new expectations about what is possible in an undergraduate classroom. Many STEM faculty have rarely (or never) been a student or a teacher in a large undergraduate class using evidence-based teaching strategies, and thus may not be able to envision the possibilities (e.g., Andrews and Lemons, 2015). For these instructors, co-teaching may expand their ideas about what a college lesson can include, how students will respond, the learning that can occur outside lectures, student capabilities, and their own abilities and preferences as instructors (e.g., Henderson *et al.*, 2009). Instructors may develop these ideas before being able to fully enact them. For example, instructors may worry that students will resist evidence-based teaching, and then observe a skilled co-teacher design and facilitate lessons with no signs of resistance and high student engagement (e.g., Henderson *et al.*, 2009). Even if instructors are not yet able to fully articulate what made these successes possible for their co-teachers, they may be able to set aside fears of student resistance and focus instead on developing their knowledge and skills.

Reflective Practice. Co-teaching may be able to cultivate critically self-reflective teachers who are equipped to continuously improve as educators throughout their careers. Co-teaching shifts teaching from a largely solitary endeavor to a collaborative undertaking in which co-teachers may have access to their collaborators' thinking, prompting reflection on their own thinking. This may create conditions for an instructor to develop a habit of noticing different things in the classroom (e.g., Orlander *et al.*, 2000). Co-teaching can be designed specifically to promote a habit of systematic self-reflection on teaching and to foster skills and ways of thinking that allow instructors to be more reflective in all of their teaching (Orlander *et al.*, 2000). This approach could have a profound impact on pedagogical change if it empowers and enables instructors to continuously improve their teaching after a co-teaching experience.

What Features of Co-teaching Experiences Foster Pedagogical Change?

There are many possible features of co-teaching that could be important for promoting changes in pedagogical approaches, particularly given that co-teaching experiences last at least several months and are complex social arrangements focused on designing, implementing, and reflecting on a course. This section outlines multiple features of co-teaching experiences that warrant additional investigation.

Collaboration. A recurring but often unexplored suggestion in prior work is that co-teachers should be highly collaborative. This raises questions about what sort of collaboration is most important for fostering changes in thinking and instructional practice toward evidence-based teaching. In addition to implementation of a course (e.g., designing assessments, facilitating lessons), discussion and reflection about class sessions or course components may also be important for promoting pedagogical change. Based on the current literature, the following aspects of collaboration in co-teaching warrant further investigation: goal setting, planning, classroom interaction, and debriefing.

Goal Setting. Co-teaching may be more likely to foster pedagogical shifts if the collaborating pair is oriented toward particular goals, including goals for teaching and goals for developing as teachers. Orlander and colleagues (2000) describe a co-teaching model developed and refined over 10 years to support the development of teachers across levels of experience. In this model, each co-teacher sets intentions before the start of

the term about how they want to shift their instruction and how they want to advance as a self-reflective teacher. Co-teachers then support each other in iteratively addressing goals and approach their teaching as learners. Future research can consider the role of goal and intention setting in driving pedagogical changes and how, if at all, this feature interacts with other features of collaboration (e.g., debriefing).

Planning. In addition to goal setting at the beginning of a term, co-planning in preparation for and through the duration of a course is another promising area of exploration. For example, in Scherer *et al.* (2020), co-instructors met regularly for co-planning meetings in which they discussed multiple course elements, including the flow and order of course topics, assignments and grading, and so on. These collaborative planning meetings allowed for generative dialogue about course content, structure, and pedagogical approaches. Depending on the structure of the collaboration and frequency of meetings, co-planning has the potential to create opportunities for articulating and hearing the rationales of other teachers, as well as for discussing teaching as challenges arise (Scherer *et al.*, 2020). Future research can investigate the influence of collaborative planning and explore the content and outcomes of these discussions on an individual's thinking and instruction.

Classroom Interaction. The time that co-teachers spend collaborating in the classroom is an area full of open questions. Is it more impactful for both teachers to be active in the classroom during the same lessons, and how should co-teachers interact? If instructors alternate leading a class session, what are the differences in experiences and outcomes if alternations occur often (e.g., every other class, every few classes) or just a few times a semester (e.g., alternating for four units)? What role does observing each other teach play in pedagogical change for co-teachers, and does it depend on level of experience or expertise? Scherer *et al.* (2020) reported that a more expert co-teacher intervening in a lesson run by a more novice instructor was a powerful learning opportunity for the novice. Yet the effect of such an interruption could vary depending on the nature of the relationship and the power and status differential of the instructors. Investigations of the experiences of co-teachers in the classroom can shed light on what fosters pedagogical change.

Debriefing. Debriefing and reflection among co-teachers may also be powerful drivers for developing new ways of thinking and instructional practice. In the cognitive apprenticeship model, teaching partnerships are designed to involve co-teachers articulating their reasoning and decision making, providing each other with feedback, and reflecting together (e.g., Beach *et al.*, 2008). Similarly, the co-teaching approach developed and refined by Orlander *et al.* (2000) specifically positions one instructor as the teacher and one as the observer during each lesson. The teacher leads a debriefing session about their own observations of the lesson, concerns, and questions. The observer facilitates the teacher's reflection and analysis of their teaching, asking questions to clarify goals and sharing observations that validate what the teacher observed. Orlander *et al.* (2000) indicate that trust is key in this aspect of co-teaching and that once a solid trusting relationship is built, observers

may offer observations that the teacher had not noticed. Participating instructors credit this model with helping them become more observant in their own teaching and appreciated that the observations of their co-teachers allowed them the chance to revisit and more deeply consider events from the lesson. Future studies should consider the role of debriefing in supporting and even accelerating changes in instructors' thinking and pedagogical change through co-teaching.

Co-teaching in an Established Course. Teaching in an existing course may also influence the implementation of evidence-based strategies. Existing course materials may be both a resource and a device for instructors' learning. For example, in a study by Henderson and colleagues (2009), novice and expert co-teachers collaborated on a course with established design principles that were grounded in education literature. The novice instructor had access to full course materials for the parts of the course they led and opted to adopt and modestly adjust about half of the given course material, while developing the other materials themselves. Similarly, novice co-teachers in Stang and Strubbe (2015) taught an established course with access to prior materials. These types of co-teaching experiences provide the opportunity to learn from expert-developed materials and gain experience developing new materials.

Instructors may also benefit and learn from how a co-teacher cultivates classroom climate. An experienced evidence-based teacher may communicate expectations and start fostering a positive classroom climate in the first few days of teaching (e.g., Harrison *et al.*, 2019; Lane *et al.*, 2021), creating a different environment for a novice co-teacher than the novice might create unaided. Thus, the way a course is designed and the materials available to co-teachers may immediately and markedly influence instructional practices. Future investigations of co-teaching should explicitly consider how these factors influence co-teachers.

Co-teacher Expertise. Most of the co-teaching studies we reviewed investigated a co-teaching pair that includes a novice instructor and an expert instructor, as defined by their level of expertise with evidence-based teaching practices (e.g., Beach *et al.*, 2008; Henderson *et al.*, 2009; Bailey and Nagamine, 2012; Scherer *et al.*, 2020). This leaves many questions about the role of co-teacher expertise in pedagogical change. Strubbe *et al.* (2019) observed that new faculty paired with instructors who were highly committed to active learning had the opportunity to learn more than new faculty paired with senior faculty who were not fully committed to active learning. This suggests that teaching experience alone is insufficient to prepare a senior co-teacher to support the development of junior colleagues toward evidence-based teaching. Research is needed to examine how co-teacher experience level and motivation to change impacts pedagogical change for the collaborator. New research should also consider what background is most critical for expert instructors in effective co-teaching pairs, such as formal pedagogical training, expertise built primarily from teaching experience, or specific expertise as an education researcher or science education specialist (e.g., Bush *et al.*, 2016). Co-teachers may also vary in career stage or position type, which could impact power dynamics within a co-teaching relationship. For example, co-teachers who were earlier in their careers than their

collaborators often felt less ownership of a co-taught course, while co-teachers at a similar career stage felt roughly equal ownership over the course (e.g., Morelock *et al.*, 2017).

Finally, while the cognitive apprenticeship model is predicated on an expert–novice co-teaching relationship, co-teaching assignments likely range in terms of the experience level of the partnered instructors (e.g., expert–expert, novice–novice). Whether and how pairs of similar experience levels, especially novice–novice pairs, can develop evidence-based teaching skills through co-teaching has not been carefully considered and merits further study. For example, novice–novice partnerships may still benefit from experiential learning of evidence-based practices through debriefing processes, which are critical in the cognitive apprenticeship model discussed earlier. Novice pairs could also be supported by guidance from an outside expert (e.g., an educational developer).

Repetition. Another potentially influential design feature of co-teaching is repetition. Do co-teachers learn and change more when they have the chance to co-teach the same course more than once? Is it equally valuable to teach the same course again, alone or with a different co-teacher? There are several reasons to think that repetition could influence outcomes. First, co-teachers may be able to build trust and more functional collaborations over time, which might better support pedagogical change. Second, the opportunity to try, reflect, and try again, at the level of the whole course, may allow co-teachers to capitalize on and extend what they learned in the first co-teaching iteration. Stang and Strubbe (2015) and Henderson and colleagues (2009) observed that instructors who had the chance to teach the same course again continued to use some (but not all) strategies they had adopted, even though they were no longer paired with an expert co-teacher. Third, the knowledge and skill development afforded by co-teaching may take time, and the complexity of effective teaching may mean that instructors benefit from the chance to learn from the same co-teacher over multiple semesters. Fourth, opportunities to fail and try again are important for learning in many domains (e.g., Simpson and Maltese, 2017; Henry *et al.*, 2019), and therefore the chance to co-teach more than once could be important for instructor development. Future research should consider the persistence of pedagogical change over time, the transfer of new ideas and practices to different courses, and how this is influenced by the chance to teach or co-teach the same course multiple times.

How Does a Teaching Evaluation System Impact Co-teaching as a Lever for Pedagogical Change?

Scholars pursuing and studying pedagogical change increasingly recognize the role that the hierarchical system of higher education can play (e.g., Corbo *et al.*, 2016; Reinholz and Apkarian, 2018; Andrews *et al.*, 2021). Co-teachers work within departments and institutional systems, and these levels of organization impact how instructors invest in changing their teaching. Teaching evaluation systems are predicted to especially influence whether and how STEM faculty invest in teaching improvement (e.g., Dennin *et al.*, 2017; Andrews *et al.*, 2021). Future studies of co-teaching should consider the teaching evaluation practices of co-teachers' departments and institutions and how these practices impact co-teaching for pedagogical change.

Insufficient Evaluation Practices. To incentivize and reward evidence-based teaching, systems must have evaluation practices that can recognize effective evidence-based teaching, including co-teaching. Yet many departments and institutions currently lack policies (i.e., what is written down) and practices (i.e., what actually happens) that robustly and equitably evaluate teaching (e.g., Dennin *et al.*, 2017; Weaver *et al.*, 2020). Relying solely on mandatory course evaluations from students is common across institutions (e.g., Berk, 2005; Dennin *et al.*, 2017) and is probably insufficient to support effective co-teaching or pedagogical change. Not only can such evaluations be biased based on the social identities of instructors (e.g., Anderson and Smith, 2005; Bedard and Kuhn, 2008; Smith and Hawkins, 2011; Boring, 2017; Fan *et al.*, 2019; Adams *et al.*, 2021; Buser *et al.*, 2022), but they may also produce misleading results (e.g., Esarey and Valdes, 2020). For example, students may underestimate learning gains in courses that implement evidence-based teaching practices (e.g., Deslauriers *et al.*, 2019). Current reform efforts steer departments toward evaluating teaching using multiple perspectives, including the perspectives of students, trained peers, and the instructor's own systematic self-reflection (e.g., Finkelstein *et al.*, 2020; Weaver *et al.*, 2020; Krishnan *et al.*, 2022).

Student Course Evaluations. Another consideration is that co-teaching itself may influence student evaluation results of the instructor and/or the course. It may be that novice instructors co-teaching with highly experienced instructors will receive less-positive student evaluations than if they taught alone, because students may rate instructors comparatively. Another possibility is that an instructor receives lower ratings when co-teaching than when teaching alone, because students dislike adjusting to different styles of teaching within one academic term. Alternatively, co-teaching could potentially improve student evaluations for an instructor or course if teaching is enhanced by the partnership. The impact of co-teaching on student evaluations has not been explored, even though instructor and course ratings may impact reward decisions (e.g., merit raises, promotion, tenure).

Research Design Challenges and Opportunities

The design of prior co-teaching research highlights challenges and opportunities for future researchers. Most studies of co-teaching to date have studied one or a few co-teaching pairs, and thus are better suited to generate hypotheses than to test them. Additionally, the co-teachers featured in research articles are often also the authors of those articles (Beach *et al.*, 2008; Henderson *et al.*, 2009; Bailey and Nagamine, 2012; Stang and Strubbe, 2015). This design offers the benefit of a deep understanding of the co-teaching context and relationship but has the disadvantage that the involved parties may be invested in seeing changes that result from co-teaching. Additionally, prior investigations have rarely systematically characterized instructors' teaching practices (evidence-based or otherwise) or studied the impact of the partnerships beyond a single academic term. These designs limit the conclusions that can be drawn. To build on existing scholarship, future co-teaching research can make the largest strides forward by addressing one or more of the limitations of prior work.

Study Scale. Two related challenges that researchers studying co-teaching face are accounting for variation and achieving a sufficiently large sample size. It is difficult to identify and recruit a sufficiently large and homogenous sample of co-teachers to investigate questions about pedagogical change and important features of co-teaching experiences. Whether, when, and with whom co-teaching occurs are typically department-level decisions, sometimes with input from faculty. Given the constraints that departments often face in meeting their teaching responsibilities and the centrality of academic freedom in faculty life, researchers will rarely find a circumstance in which they can assign faculty to particular co-teaching conditions. Additionally, many circumstances in which departments assign more than one teacher to a course are not co-teaching, as we define it, because instructors largely carry out the work of teaching independently. Looking beyond departmental instructor pairings, apprenticeship-model programs (e.g., National Institutes of Health Institutional Research and Academic Career Development Awards)—in which “future faculty” trainees engage in professional development and mentored teaching experiences—may be a target for recruiting co-teaching pairs. However, how commonly these mentored arrangements constitute co-teaching is also unclear. These realities mean that most studies will have quasi-experimental designs, which can offer robust ecological validity (i.e., ability to generalize to the real world), but may be unable to control for important variation across co-teaching pairs.

Another challenge for co-teaching research is the complexity of the entity being studied and the in-depth data needed to make sense of it. A strength of the existing work is the researcher’s use of diverse data sources and rich qualitative analysis. Indeed, we caution future researchers against the urge to simplify by quantifying. Studying co-teaching as pedagogical change will require close observation and interviews to understand thinking and experiences that are not readily observable. Case studies may remain the most robust research design for understanding the impact of co-teaching. Extracting more generalizable findings will then require synthesizing across case studies conducted in different contexts. Generalizing across studies conducted in different contexts is easier if researchers rely on similar theories to ground their research (Reinholz and Andrews, 2020).

Systematically Characterizing Pedagogical Change. Though existing work hints that co-teaching can contribute to the adoption of evidence-based teaching strategies (e.g., Beach *et al.*, 2008; Henderson *et al.*, 2009; Stang and Strubbe, 2015; Strubbe *et al.*, 2019), testing this hypothesis requires systematically characterizing instructional practices and documenting how they change over time. The research community has developed and refined a variety of classroom observation protocols that may be appropriate for documenting pedagogical change resulting from co-teaching.

The choice of research-based tools to examine the impacts of co-teaching will depend on the participants and how instruction is expected to change as a result of the teaching partnership. For example, researchers studying the practices of instructors who previously taught primarily by lecturing could use a tool that quantifies class time spent on lecture and class time spent on other activities (e.g., Smith *et al.*, 2013;

Owens *et al.*, 2017). Other tools could also be useful for investigating the implementation and fidelity of evidence-based practices as a result of co-teaching experiences (e.g., Crowe *et al.*, 2008; Eddy *et al.*, 2015; Tekkumru Kisa *et al.*, 2015; Arneson and Offerdahl, 2018; Kranzfelder *et al.*, 2019).

Testing the hypothesis that co-teaching facilitates changes in instructional practices requires measuring practices as they change across time, potentially with a high number of classroom observations. Recent research indicates that many more classroom observations per term are needed to document change than has sometimes been recommended. Previously, researchers suggested that at least four observations per instructor per semester were needed (e.g., Stains *et al.*, 2018), but two different research groups have since demonstrated that four observations are often inadequate to reliably document instructional change across time (Sbeglia *et al.*, 2021; Weston *et al.*, 2021). In addition to needing many observation points within a term, researchers may also need to document instructional practices across multiple terms for co-teachers. For example, researchers might measure instructional practices in the same course in a term before co-teaching is implemented, during the co-teaching term, and in subsequent terms, and then characterize whether and how instructional practices changed. Furthermore, additional terms of co-teaching may support additional pedagogical change, necessitating even longer study designs.

CONCLUSIONS

Our initial curiosity about co-teaching as a lever for pedagogical change has only been amplified by our work on this essay. Prior work suggests that co-teaching has the potential to lead to the development of new ways of thinking and the use of evidence-based teaching strategies. Future research can establish what it takes to leverage co-teaching for pedagogical change, what change is possible, for whom, and in what contexts. As that work progresses, we must also consider what it would take to transform co-teaching into a widespread and systemic approach to pedagogical change. What shifts in resources, culture, and practices would departments and universities need to undertake to adopt and maintain co-teaching as an organizational lever to advance evidence-based teaching?

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