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Co-teaching as a model for scholarly interactions and the acceptance of limits to knowledge

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Co-teaching has been shown to be an effective instructional tool in a range of academic settings. In this contribution, we are extending the list of benefits. Using quantitative and qualitative approaches, we assessed the impact of a co-taught, interdisciplinary course on students' perception of their own role as scholars, and on how students interact with their peers and their instructors in the classroom. Students clearly perceived and appreciated the benefits of having two professors from two different disciplines teaching an interdisciplinary course. They also paid close attention to the interaction between the instructors, noting that they rarely see scholars question or correct each other. Students recognized that there are limits to any scholar's knowledge, and that it is normal for researchers to ask questions of one another. Importantly, they came to see interactions between co-teachers as a model for their own role and behavior as scholars, and they took an acceptance of limits to knowledge with them beyond this one co-taught course.

KEYWORDS

co-teaching, inter-disciplinary courses, scholarly communication, university teaching and learning, critical thinking (skills), teacher and learner roles, transferrable skills

Introduction

Co-teaching has been practiced and studied in many educational contexts. Collaborative teaching approaches were developed by general and special education teachers to support the integration of children requiring accommodations into diverse classrooms (Vembye et al., 2024). Similar approaches have also been taken in higher education settings and recognized for their effectiveness in supporting diverse student bodies as well as diverse perspectives (Nápoles, 2024; Zach, 2020). Research on co-teaching in higher education demonstrates its effectiveness in fields as varied as design (Self and Baek, 2017), nursing (Chanmugam and Gerlach, 2013; Jarvis and Kariuki, 2017; Lock et al., 2018), English (Barahona, 2017), sports sciences (Zach and Avugos, 2024), and teacher education (Burns and Mintzberg, 2019; Heck and Bacharach, 2015; Oh et al., 2017; Stobaugh and Everson, 2019). The reasons to launch a co-taught university course vary widely, but they often include the goals of broadening perspectives and expertise among students, and diversifying course content (Helms et al., 2005; de Welde et al., 2014). Benefits of this type of teaching can also accrue to instructors, for instance by pairing up junior faculty members or graduate students with more experienced professors, thus providing guidance for the newer instructor and new ideas for the senior colleague

(Buckingham et al., 2021; Cordie et al., 2020; Liebel et al., 2017; Walters and Mistra, 2013).

We would like to offer yet another benefit to the co-teaching arrangement from the student's perspective: students are able to observe the interactions of the instructors. This, of course, is evident to anyone considering a co-teaching arrangement where both faculty members are teaching and engaged simultaneously; less foreseeable was the effect such an arrangement has on the students. To them, it was new to witness instructors admit to not knowing all the material in a course, openly ask for help, even make mistakes and accept corrections. After making these observations, the students felt more comfortable asking questions and risking mistakes themselves. This comfort translated not only into other courses, but also into contexts beyond the formal setting of their postsecondary education.

The aim of this paper is to present the type of interactions and changes in students' perceptions that were happening in a co-taught course, and to show that the students themselves found that they developed a new outlook and mindset. One of the current debates about the value of a university education contrasts the importance of learning expert content with the development of new skills and ways of thinking (e.g., Cowan, 2021; Danisch, 2021; Trinidad et al., 2021). Co-teaching helps achieve both these goals by helping students cultivate a deeper understanding of complex topics as well as more flexible patterns of thought. Students, faculty, administrators, and governments are interested in how well education meets goals of personal growth, societal progress, and professionalization (Bonnard, 2020; Brooks et al., 2020; Trinidad et al., 2021). Students in a co-taught interdisciplinary course ask new questions about themselves and their place in the world, and they become more confident in their ability to solve big problems.

Course setting and design

Our course was the result of discussions between two faculty members (C. R. and M. C.) about topics relating to both our fields, ecology and history, and the recognition that we both share common interests and curiosity about each other's respective areas of research. We decided to focus on the historical and ecological consequences of early modern contact with a focus on the "Columbian Exchange." This term refers to the transfer of plants, animals, and microbes across the Atlantic in the wake of Christopher Columbus' voyages at the end of the 15th century (Crosby, 2003). In the years since Crosby first coined the term in 1972, historians and ecologists have produced a large body of research showing how the transfer was transformative to ecologies and cultures around the Atlantic, and later around the world (Cook, 2015; Mann, 2019).

We built the course around the following four course goals and four learning objectives:

1. Understand the basic outlines of how ecologies and societies changed as a result of the "Columbian Exchange."
2. Engage with current debates and uncertainties in the fields of ecology and history.
3. Make use of primary and secondary sources to interpret the past, and make use of records of the past to understand the present.

4. Develop a sense of stewardship for the past, a sense of responsibility for our role in the present, and an ethical engagement with the politics of historical memory and environmental impact.

By the end of this course, students should be able to:

1. Describe and analyze the significance of people and events that shaped exploration, contact, and exchange in the early modern world;
2. Interpret evidence from multiple perspectives;
3. Read primary and secondary sources with a sympathetic yet critical eye;
4. Create and present a clear and persuasive research project.

We designed the first implementation of the course as part of a series of 2nd-year courses offered by the Centre for Student Engagement. Students needed to apply for acceptance into the course, and the prerequisite was to have completed one of a selection of 1st-year seminar courses, which were only offered to students entering university with an academic scholarship. After teaching the course within this framework in 2019 and 2020, we are now teaching this course as a regular 4th-year course jointly offered between the programs of Biology and History. All students with credits from a 3rd-year course either in Biology or History can apply regardless of their grade averages, and they can use the course for a credit in either a Biology or a History program, as well as a breadth course for either Sciences of Humanities. The course is capped at 20 students, and until now we have been able to accept all students who applied. We plan our 2-h long weekly meetings as seminar-style discussions, which are frequently fronted by short lectures to introduce topics or concepts. Students can also join us on an optional week-long trip to visit sites of ecological and historical significance in the Dominican Republic during the winter semester reading break. However, this paper focuses on the possible influence of co-teaching in the classroom only, includes responses from all students, regardless of whether they joined the trip or not, and survey questions that were phrased to refer only to interactions during the regular class session on campus.

We assessed student contributions mainly through a scaffolded course project, for which students developed a topic and which they could choose to undertake as part of a team. In addition, we scored their active participation in our meetings and students completed a short end-of-course reflection.

Co-teaching an interdisciplinary course

Since the origin of this course was our respective interests, we structured the course, from the outset, around a co-teaching approach. Authors have defined co-teaching in several different ways and have used a range of terms for the same approach (Anderson and Speck, 1998; Carpenter et al., 2007; Yanamandram and Noble, 2006). Since our argument centers on benefits for both students and instructors, we define co-teaching following Deighton (1971) as a type of collaborative teaching in which multiple instructors share the responsibility, planning, presenting, and assessing in a specific course.

This type of co-teaching also reflects the interdisciplinary nature of the course content. An essential component of co-teaching interdisciplinarity for us is the faculty members' cooperation and interaction at all stages of the course's progress: from planning to classroom instruction, as well as assessment and evaluation, all in the same shared physical space (Burns and Mintzberg, 2019; Crow and Smith, 2005). In our case, both instructors collaborate on the course outline and its schedule of readings. These readings are deliberately chosen to support interpretations from both ecological and historical perspectives. The two instructors are present at every meeting, actively leading part of each session, and participating in all discussions. We are also both present at every assessment, meeting in person for the grading of written assignments, and marking the oral presentations as a jury of two. We ask students to address their email communications to both of us, and we both respond. If the person responding first is not the subject expert, we may defer some points to the up-coming response from the other instructor, but students receive feedback from both of us. We also hold office hours together. This visible collaboration both within and outside of class time ensures that students can always get detailed advice from the expert in the most relevant field, and demonstrates that the teaching of this course, in all its aspects, is consistently a team effort.

By co-teaching every aspect of the course, we and the students analyze, synthesize, and harmonize the links between our disciplines of ecology and history in a coordinated and coherent way (Choi and Pak, 2006). We prioritize integration and reciprocity in order to bring about "a synthesis of diverse disciplinary perspectives leading to a new level of thinking and studying a topic" (Fawcett, 2013; p. 376). By working closely together at all stages of the course, we are also encouraging the students to practice epistemological pluralism: we are guiding them toward an acknowledgment that there is validity in multiple ways of knowing things, working with them to integrate the epistemologies of different disciplines so that we could come to a more complete understanding of complex issues, and showing them that researchers from contrasting fields can work together to accommodate different disciplinary approaches (Miller et al., 2008). In order to reach this epistemological pluralism, we—the instructors—need to transfer our own knowledge to new areas.

Based on our readings of the literature on co-teaching, we expected two clear benefits for the students from this co-teaching approach. The first benefit relates to the learning outcomes that we wanted students to achieve. Students must deal with, live in, and understand an increasingly connected, complicated, and dynamic world. It is becoming less important to know terms, concepts, and other static topics (Petersen et al., 2020); concurrently, it is becoming ever more important to find and assess diverse sources and types of information, and then appropriately evaluate, analyze, and integrate the information we receive (e.g., Common Core Standards Initiative, 2020). By crossing disciplinary boundaries, we can challenge students to search for different patterns, develop new and diverse strategies, and think along varying lines of evidence (Carpenter et al., 2007). By embracing deep interdisciplinarity, we can reveal to students that every academic discipline is indebted to many others, and we can demonstrate that the true scope of any one discipline is messy, its borders porous (Krometis et al.,

2011; Renshaw and Valiquette, 2017). The breadth of content and concepts, types of information, and unfamiliarity with at least some of these notions encourage students to explore new links and think beyond accustomed limits, thus supporting the development of relational and extended abstract thinking (Biggs, 2003; Biggs and Collis, 1982). Consequently, a co-teaching approach with representatives from different disciplines offers an ideal and conducive venue for developing students' abilities to deal with the growing complexity of a dynamic environment.

The second benefit that we expected comes from the way that co-teaching changes the dynamics of how we as instructors learn from each other. We expected to learn from each other's teaching. Normally, we learn from colleagues when we attend our professional associations' conferences, teaching and learning workshops, or other formal events. Alternatively, we may have colleagues observe our teaching and then provide comments. Either way, it is our decision whether and how we use what we have been told: we may integrate some aspects and not others into our own teaching. In a co-teaching context, we also have the opportunity to observe each other, but the decision of how we teach becomes a decision that needs to be shared between the co-teaching instructors (Sheriff LeVan and King, 2015). Rather than making solitary decisions, co-teaching colleagues share power in determining what and how content is being taught. This sharing forces instructors to learn from each other and to consider new approaches. It also encourages instructors to deliberate how they evaluate the effectiveness of their approaches and methods, and how they weigh potential improvements. Again, the important aspect here is that the reflexive practice is done in collaboration with a colleague. As Sheriff LeVan and King (2015) have argued, co-teaching can lead to the examination of existing assumptions, preferences, and long-held beliefs. As a result, the co-instructors can amplify the effectiveness of their teaching from the team-taught course into their individual courses.

Interacting with the students during the seminar and reading their reflections and course evaluations at the end of term, we realized that there was a third benefit which we did not anticipate, but nevertheless may be the most significant impact: our visibly cooperative approach made it obvious to students that we are all learners. In a traditionally taught course, there is a clear division between those who (purportedly) know—the instructors—and those who (ideally) learn—the students. This distinction is only rarely removed or diminished. In co-teaching, however, the line gets blurred every time a concept from one field is introduced or discussed and the instructor whose training was in the other field asks questions or makes mistakes. To listeners and participants, professors become model learners and exemplars of mutual respect (Anderson and Speck, 1998). In our course, for example, discussing the history of the trans-Atlantic slave trade nudged the ecology instructor into a more traditional student role, whereas introducing the concept of island biogeography turned the history expert into a novice. Learning new concepts is, of course, nothing new for faculty as researchers or instructors, but students do not usually observe us in the role of a learner. By applying our expertise from one field to a challenge in an unfamiliar area, we were effectively demonstrating how to transfer skills in order to broaden and deepen our learning.

However, we were not always immediately successful in our attempts to learn new things, and each of us needed to ask the other for help. As we found out, seeing professors ask questions of each other was a pivotal and memorable experience for our students. They commented on the fact that they had never seen professors interact in this way. Although we had not foreseen this outcome, and therefore had not designed our co-teaching course with this in mind, our explicit status as learners in the course became a model of how researchers interact with, and learn from, each other. Students pointed out that it helped them understand how, in an academic context, observations and results are discussed, and what it means to critically evaluate statements in a professional or collegial setting (see Results section).

This realization was so far only based on our casual interactions with students and their written feedback. We wanted to find out whether students recognize this impact themselves after the course was over, and how important they feel this impact is for their academic progress within and outside an academic setting.

Our goals for the current investigation are 2-fold. First, we want to know whether students perceived our co-teaching approach to be a crucial factor in their learning of the course material, and which aspects of their learning they thought were mostly influenced by our co-teaching in particular. We answered the question of how our co-teaching shaped students' learning by using a survey instrument. Secondly, we were interested in looking for signs of deeper learning by finding out whether students thought the skills they gained from our co-teaching would help them beyond the course and their academic program. We assessed the question of whether our co-teaching helped students to develop skills that would be useful beyond their academic program through a qualitative analysis of students' reflections.

Methods

To shed light on these questions from different angles, we used three sources of data. First, we designed a pair of surveys that were administered to the students at the start and end of the semester in 2022. These surveys aimed to identify the students' perception of co-teaching and a self-evaluation of a given set of skills. The surveys were based on existing tools and consisted of Likert-scale type questions and essay-style questions (see [Supplementary material](#)).

All Likert questions for the pre- and post-course surveys used standard five-level scale (strongly disagree–strongly agree) and were divided into sub-sections for participants to self-evaluate a set of skills and opinions: perceived competence in communication (four items), seeking help (four items), perception of academic failure (five/four items), expectations/perceptions of the class and co-teaching perception (four-six items). Students were asked to provide their own definitions of communication and academic failure in order to mitigate response bias prior to answering the Likert questions to ensure that the answers reflected their own interpretation of the concepts. The final section of the survey consisted of open-ended questions related to co-teaching and space for students to provide additional reflections on the topic, class, or survey.

These course surveys were administered online through the university's learning management system. A staff member in the Biology department who was not involved in the course assigned survey ID numbers to each individual student to allow matching of pre- and post-course responses. The staff member then anonymized the surveys by removing all identifying information from the responses. The instructors only had access to the anonymized survey responses after the completion and submission of final course marks.

Next, we sent an adapted version of the post-survey to students who had taken a previous version of our course in 2019 and 2020. This survey covered the same themes as the post-survey (communication, help-seeking behaviors, and overall co-teaching perception) and added additional sections asking participants to identify their concerns and limitations surrounding academic learning and course delivery. This survey for past students was administered through Google forms.

Finally, we asked students in the 2022 cohort whether they would also be willing to share their final essay-style reflections submitted at the end of the course for this research. This request to the students was made after the completion and submission of final course marks.

Following a convergent mixed method study design, we analyzed all of the data in parallel, either quantitatively in the case of the Likert-type questions, or qualitatively in the case of the essay-style questions and the reflections.

Of the ten students in the 2022 cohort, nine completed the pre-course survey, while eight also answered the post-course survey. Four of them permitted us to use their final course reflection for this research. Three quarters of the students were female ($n = 6$). The respondents' ages ranged from 20 to 26 years, and they were in their third to 5th year of study.

We sent our invitation to participate in the adapted survey to 31 former students (2019 and 2020). Nine of them completed the survey. The majority ($n = 6$) of respondents were female. They had taken our course in their second or third year of study and had been enrolled in a wide variety of programs beyond Biology and History. All of them are currently either working in industry or are pursuing graduate degrees.

Likert responses were converted to numerical values on a 5-point scale, with higher values reflecting stronger agreement with the question statement. Where students responded to both surveys, we were able to determine whether students' answers changed after completing the course. First, we subtracted the students' post-survey response values from their respective pre-survey values (positive averages indicating that students agree more with the question statement after the course, negative averages indicating less agreement, and zero signifying no change). We then averaged these differences over the questions relating to competence in communication, help-seeking behavior, and attitudes toward failure. To determine whether students' responses changed after the course (i.e., where the average numerical differences between surveys did not equal zero), we performed single-sample *t*-tests in RStudio ([Posit team, 2025](#)).

Open-ended questions in the pre- and post-survey pertaining to defining perceived competence in communication, help seeking behaviors, perception of academic failure, and co-teaching were

analyzed qualitatively using inductive content analysis. Responses were coded for recurring keywords and concepts that reflect how students understood each notion. These codes were then grouped into categories based on shared meaning. We determined the frequency of occurrence of these key terms or concepts within each response time point to examine changes in students' perspectives over time. We then compared the frequencies of these concepts between the pre- and post-survey responses to explore how participants' definitions or opinions may have evolved throughout the course.

In contrast, we analyzed essay-responses and post-course reflections from both survey groups (2022 cohort and former students) using an inductive thematic analysis conducted in NVIVO (QSR International, 2019, Version 12.7)¹, to identify meaningful and broader themes related to students' experiences with the course and the co-teaching model. This process involved a systematic approach, beginning with an initial review of the responses to identify recurrent patterns based on contextual meaning. Initial coding was performed manually by labeling phrases and excerpts as nodes to capture participants key ideas or experiences. NVIVO facilitated the organization, comparison, and retrieval of coded text segments, allowing for efficient refinement of emerging patterns. Similar nodes were subsequently grouped together using NVIVO's categorization tool, which aids in the consolidation of sub-groups into broader higher-order themes. Themes were not pre-determined but rather emerged inductively from patterns identified in the coded data. The grouping and coding process were refined iteratively through repeated reviews of the data to ensure consistency and coherence. The final themes were identified across the students' responses and exemplary quotes and statements were selected to illustrate key insights emerging from the data.

Results

At the beginning of the 2022 iteration of the course, students self-reported feeling confident communicating with peers in small or large settings and seeking help or feedback. Most of them indicated that they had experienced failure in the academic context, worrying about what others might think of them, but were also willing to accept criticism from peers or instructors. The only ambiguous response was to the questions as to whether they would seek help rather than trouble-shoot themselves. Students indicated a very positive attitude toward the course and the instructors and revealed a high interest in the course topics. Of the nine students responding to the pre-class survey, four had previously taken co-instructed courses.

Analysis of the 2022 Likert-type pre-course and post-course surveys (Figure 1) indicated that students did not change their responses to the survey questions regarding their self-assessment of their competence in communicating, help seeking behavior, and perception of failure, after completing the course (Table 1).

In the post-course surveys across all 3 years, students responded overwhelmingly positively to our questions about their experiences on how the instructors had presented material and interacted with

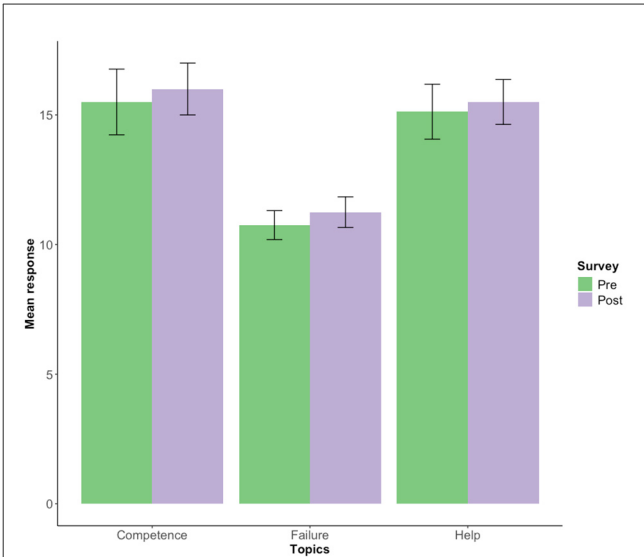


FIGURE 1
Comparison of mean responses (± 1 se) between pre-course and post-course surveys for the three survey topics. Higher mean values reflect increased communication skills, willingness to seek or accept help, and increased reflection about failure or criticism, respectively. Sample size was eight for all questions.

TABLE 1 Students' differences in responses from the pre-course survey to the post-course survey.

Topic	t-value	p-value
Competence (Section B)	0.59	0.58
Help seeking (Section C)	1.03	0.34
Failure (Section D)	0.84	0.43

Tests were one-sample *t*-tests conducted on composite scores, assuming that the mean difference between each student's response to the surveys equals zero (i.e., no difference between surveys). Sample size was eight for all tests.

students, how the students understood content and readings, and whether they would sign up for a co-taught course again.

When responding to the open-ended questions, students from all 3 years mostly agreed on what effective communication is to them: it should be clear and concise, have a well-defined intent, and involve active listening. These were main points in both pre- and post-surveys. However, five students also discussed methods of communication in the pre-survey, while only one student brought up this point again in the post-course survey. This may suggest a subtle shift in how students define effective communication, which is not reflected in the Likert response but may explain some of the unchanged self-assessment.

We also asked students about their preferred means of getting help. Most students appreciated feedback from instructors and discussions with their colleagues, and this did not change between pre- and post-surveys. More students thought that asking questions and external sources enhanced their learning at the completion of the course compared to the start.

Students' responses to questions about their perception of failure were more variable. In the pre-course survey, most students mentioned a lack of understanding and effort, as well as not

1 <https://lumivero.com/products/nvivo/>

achieving a grade or goal, as constituting a failure. While this latter point remained important in the post-course survey, students now also talked about learning from their failure. For example, one student defined failure as “Failing a course, and not learning anything from the experience of failure.”

The theme that was mentioned most often by students—both those still in the course when providing the feedback and those who had already completed the course—was that of complexity. Aware of how complex important issues can be, students expressed an appreciation for hearing a variety of perspectives from their instructors. One student wrote at the start of the semester that “diversity of ideas” and “different educational experiences of instructors” were among the advantages of being in a team-taught course. This same student wrote at the end of the semester that students could “learn from both instructors who each have their own perspective on content that is taught in the course, which will be helpful in gaining a wider understanding of material” as well as being able “to gain understanding of topics you would not have explored before.” Other students wrote of the instructors’ “multiple perspectives” and “differing perspectives” as leading to a fuller understanding of course material. One past student of the course wrote that “it was fascinating to see how differently both instructors viewed the same piece of information purely as a result of their educational backgrounds,” and another past student said that it was “great to hear two different but interrelated perspectives on one topic area.”

Since this course was taught by instructors from two very different academic disciplines (ecology and history), the level of diversity that students perceived was likely higher than would be the case in most other team-taught courses. A few students noted a potential drawback to the intrinsically interdisciplinary context of the course: the difficulty of presenting materials from different academic disciplines to a group of students who did not share the same academic background. As one past student explained, “the material has to be basic enough so as to be understood by students from both backgrounds” of biology and history. This student emphasized that the level of instruction served them well—a history student learning basic biological concepts—but worried that “perhaps those with a more intermediate background would not have gained much.” Another past student expressed an opinion that the diversity of perspectives led to too much work, saying “I also felt we covered 1.5x more material than is usual” for a course at that level, “on account of having to cover concepts from two backgrounds. At times it was overwhelming.” These specific concerns were not raised by other students in their comments, however, suggesting perhaps that they were not especially widespread. In fact, the comments from other students who had completed the course show that the same potential drawbacks for some were actually perceived as positive outcomes by others. On the diverse academic backgrounds of students in the class, one student wrote that “having a wide range of student backgrounds in the course (history, chemistry, psychology, paleontology, anthropology, among others) provided a unique and exceptional experience.” On the pacing of instruction and overall amount of work, another student wrote that “the course was meant to spark new ideas by thinking deeply, slowly, and critically about the old ones. Unlike many courses in university, this course was

not about trying to understand as much knowledge as possible in a short span of time. Rather, the instructors took the time to help us engage deeply with a few ideas, which was a much more meaningful and rich learning experience.”

The theme of complexity in students’ comments was often linked not simply with team teaching in and of itself, but with interdisciplinary team teaching in particular. As one past student put it, the interdisciplinary perspectives allowed for “inclusive understanding,” and added that “interdisciplinary learning” is “often far better and holistic.” One student reflected on the impact this can have on understanding key terms: “... learning about concepts from both perspectives, for example, the definition of the word “colonization,” was really meaningful. I had never considered that words can have vastly different meanings based on the lens we look at them with. Furthermore, it also taught me the importance of considering the perspectives of different academic disciplines and how it can further enrich the understanding of one specific discipline.”

For several students, the interdisciplinary team teaching helped guide them toward the conclusion that different academic disciplines are not really so separate as the structuring of universities into departments would make them seem. The very word “seemingly” makes the point quite clearly in several comments, with one student describing the professors as coming from “*seemingly* and superficially opposite subjects,” and another writing that “team teaching’s effectiveness lies in converging the two *seemingly* unrelated subjects” (emphasis added). Some students focused on the connections between the specific disciplines that they associated with these instructors. For example, one wrote at the end of the semester that “the main advantage of this course is because the subject [sic] of ecology and history fit in so synergistically.” Another expressed a similar thought by writing at the start of the semester that “having two instructors in different areas of study is advantageous because it will connect aspects of the course through different perspectives. Rather than looking at something from only a historical or biological perspective it will make us think how the history changed the biology or vice versa.” This student had their predictions confirmed, writing at the end of the semester, “I think having two instructors widened perspective [sic] about the content” and “we were able to learn and look at reading from both perspectives.” Other students moved beyond the two specific disciplines in this course by commenting about the larger value of linking academic disciplines and expressed more broadly the same idea about approaching a topic from different disciplinary traditions in order to enrich understanding. For example, past students described the team faculty in the course as “equal partners provid[ing] their separate expertise on a joint experience,” “experts in different fields teaching a topic where their fields intersect,” and as people having “different perspectives, with the same learning goals.” Evocatively, one past student wrote that “team-teaching works effectively because it reminds us that everything is polyphonic” and “reminds us that there are many perspectives, many methods.” Another stated succinctly, “the more curious erudite scholars in a room, the better!!”

A second theme that students frequently mentioned throughout our surveys relates to the limits of knowledge, noting that the course was taught by “professors [who] have

different areas of expertise,” implying “different ideas” and “different backgrounds” as well as “gaps in knowledge” and a willingness to “acknowledge one’s limitations.” Comments generally referred to the fact that we dealt with knowledge and concepts from two different fields of study, the willingness to learn from other experts, and the need for trust and respect to make this possible. Many comments observed how the instructors acknowledged and handled the limits to their own personal knowledge. Some comments pointed out how students themselves could either learn from this display or how it influenced their willingness to participate in the course. Interestingly, in the post-course survey, students focused their comments on how the instructors dealt with these differences. One student mentioned that the instructors “fill[ed] in the gaps of each other’s knowledge,” while another observed that the instructors “had a good understanding of each other’s material and if they didn’t then they would ask for clarification and explanations to clear up confusion.” Another student said in their end-of-semester course evaluation, “the professors worked collaboratively and produced coherent, thought-provoking and informative lectures every week.” The result of this “collaboration between the instructors” was a “weaving together [of] each others [sic] skills and knowledge.”

Both current and past students also commented on the fact that the instructors’ willingness to ask each other questions reflects a basic willingness to learn from other experts. As one student put it: “each professor was genuinely interested in learning more about the other discipline.” Another student used a wider viewpoint to comment on this collaboration: “Team teaching is denying the myth of self-sufficiency by inviting others’ strengths (and weaknesses) into our plans.” Importantly, students noted that the instructors were willing to learn not only from each other but also from the students in the course.

It speaks to the students’ perceptiveness of the instructors’ interactions that comments from current and past students acknowledge that this type of co-teaching in an interdisciplinary context requires respect and trust. It starts with “instructors need[ing] to be able to recognize when their expertise and insight is needed and when it is not.” Another student made a similar point: “[the] strength of one prof could be weakness of other and weakness of one prof could be strength of other.” However, several students noted that this recognition requires mutual respect and trust. One of them defined it as: “if the professors don’t respect each other, they might undermine each others [sic] opinions.”

Finally, students found that co-teaching allowed them the opportunity for deep learning of skills that could be applied in other courses as well as in non-academic or professional settings. Most generally, this was reflected in comments relating to the “polyphony of the wider world” quoted above. Dealing with complex, interconnected, and varied topics permitted students to develop a background and set of strategies to deal with such topics. Students pointed out that the course allowed them to develop the “ability to tackle problems from different angles” and noted that the course “mimics what the ‘real world’ acts like being inter/trans disciplinary.” Another student expanded on this by explaining that the course allowed them “to engage with multiple perspectives.

Course disciplines are arbitrary, and these divisions do not exist in the real world. Vaccine rollouts, for example, have so many implications in so many disciplines, and being in a co-taught course helped me appreciate the importance of considering multiple perspectives for real-world issues.”

Many students also commented on the impact of the course on their critical thinking and communication skills. One student explained that the course “makes me think intentionally of the way I view anything, whether it be a problem requiring a solution or merely some material/content I am consuming.” Another student listed how the course had helped them with “communication, taking charge of a conversation, learning to work with alternate perspectives, working with new people closely.” Several of them stressed how they became more comfortable participating and speaking during class: “This class helped me become more comfortable speaking up in class and really learning as I go along. After this class, I have been able to engage more in my courses because I feel more comfortable taking that initiative to speak to my classmates and professors.” In their reflection, a former student explained how observing the interactions between the instructors encouraged them to participate: “Being a biology student, initially in course discussions I was hesitant in asking basic questions about the historical perspective as I didn’t want to be judged by my peers and professors. However, when [Ecology professor] would ask [Historical Studies professor] clarification questions about the historical perspective with a genuine interest and vice-versa it motivated me to also ask more questions and participate even more because it was an open and safe space for discussion.”

Similarly, another student explained that the course had “taught me how to effectively participate and facilitate discussions with my peers and professors.” This increased communication also allowed students to teach each other: “Learning from and teaching your peers in addition to lecturers/teachers. It means having an opportunity to teach the class about a specific topic and having peers teach and learn as well (so that everyone has an opportunity to contribute to the learning process).”

Discussion

Overall, students from all 3 years saw themselves as active communicators who knew when and where to ask for help. They appreciated the different nature of our co-teaching model and identified advantages and possible disadvantages.

Taking the course did not change their opinions and perceptions on these self-reported aspects. This consistency does not come as a surprise. Most students who enrolled in each of the 3 years generally had high grade point averages and were already engaged and interested students when they started in our course. Thus, there was little room for “improvement.” Also, small sample sizes resulted in low statistical power, making it unlikely that we could detect such necessarily small changes as significant. Nevertheless, the students recognized the opportunities this type of teaching offered them in contrast to a more traditional forms of course deliveries. Their open responses clearly support our suggestion that co-teaching can serve as a

model for scholarly interactions and can help identify limits of knowledge, then broaden our various perspectives. These results indicate that our course not only reinforced students' positive expectations and attitudes toward co-teaching, but also highlighted additional advantages of this teaching model.

Our interpretation of these student comments is supported by plenty of research. Not surprisingly, co-teaching is frequently linked to the teaching of interdisciplinary topics (Krometis et al., 2011; Rooks et al., 2022; Shibley, 2006). The benefit is not limited to the presence of two content experts covering two fields, but importantly also allows for the breaking down of barriers between otherwise separate fields (Krometis et al., 2011). Additionally, co-teaching has been considered as the most appropriate teaching method for complex topics. For example, Nandan and London (2013) called for co-teaching as a means to solve “wicked problems.”

While our discussion here centers on the effects of co-teaching, this focus does not imply that co-teaching is the only factor that influenced our students' learning, participation, and communication. For example, as we point out above, this course employed a seminar-style approach. The effectiveness of such an active teaching strategy in fostering improved conceptual understanding (Cleveland et al., 2017), higher grades (Freeman et al., 2014), or critical thinking skills (Styers et al., 2018) has already been well established. Therefore, our discussion here aims to shed some light on the specific ways in which co-teaching can add to these benefits of active learning strategies.

While co-teaching facilitated learning of broader and more complex topics, students also noted that it highlights the limits of knowledge—of each instructor, each field of inquiry (Liebel et al., 2017) and of best pedagogical approaches (Haag et al., 2023; Yanamandram and Noble, 2006). These aspects of co-teaching require a willingness to learn from both instructors and necessitate a good deal of trust between the instructors themselves (King et al., 2019; Morelock et al., 2017). The fact that students recognized this requirement is important, since it has previously been shown that students can perceive instructors apparently criticizing each other or not knowing something as problematic (Stork and Hartley, 2009). In turn, the relationship between instructors can then serve as a model for learning and scholarly interaction for students (Smith and Winn, 2017).

Finally, students commented on the fact that co-teaching in this course taught them skills that they expect to be able to use throughout their academic career as well as outside of academia. Probably most obvious is the fact that the interdisciplinary nature of the course mirrors both “our globalized world [that] is increasingly complex” (Bass et al., 2023) and increasing pressure on academic institutions to solve problems that span traditional disciplines (Fam et al., 2020). Students also appreciated the opportunity to learn from each other. Peer instruction has been shown to be an effective teaching practice that can lead to an increase in performance and problem-solving skills along with a reduction in attrition rates (Vickrey et al., 2015; Batz et al., 2015).

Taken together, the evidence we present here indicates that students recognized and appreciated the different nature of instruction in a co-taught course. Specifically, they did not see the

instructors merely as providers and assessors of knowledge, but rather as models for scholarly interaction. As a teaching approach, modeling is rooted in social learning theory's simple yet persuasive idea that humans, as social creatures, learn through observing others—their models—and through making sense of what they have observed in order to reproduce the behaviors they would like to emulate (Bandura, 1977). Learning from models can be complex and haphazard, yet also very powerful when students are able to pay attention to a behavior, internalize what they have seen, reproduce the behavior in their own actions, and be motivated to enact the behavior they have observed (Horsburgh and Ippolito, 2018). The students' responses to observing their professors ask questions and receive feedback from one another suggests that co-teaching might reduce the apprehension and embarrassment that students feel about receiving instructors' feedback in front of other students (Malachowski et al., 2013).

One of the unexpected outcomes of the course, not previously observed, were students' comments on how the interactions between the professors had an impact on their thinking about scholarly discourse, the value of their own thinking and questions, and about their roles as researchers.

The students' responses illustrate that they gained a new understanding of how scholars interact with each other: while informed debates are clearly part of these interactions, questions and explanations are equally integral and essential to learning in higher education. In turn, this realization allowed students to ask their own questions. Several of the students commented on the fact that they used some of the skills gained in our course in later courses or after they graduated. For instance, one student pointed out that our co-teaching “makes me think intentionally of the way I view anything, whether it be a problem requiring a solution or merely some material/content I am consuming.” Another student highlighted that as a result of the course, they would “try to engage with multiple perspectives. Course disciplines are arbitrary, and these divisions do not exist in the real world. Vaccine rollouts, for example, have so many implications in so many disciplines, and being in a co-taught course helped me appreciate the importance of considering multiple perspectives for real-world issues.” Finally, a student reflected on how co-teaching has changed their outlook: “... comparing my knowledge before the course and after, I can say that this course has made me more observant, [...] it has led me to be more critical of literature I read. I hope to carry this knowledge with me as I continue to grow as a lifelong learner, and I tend to grow my knowledge within the history and ecology realm as I have found both fields are necessary to get a grasp and understanding of the past.”

Taken together, these changes reflect transformative learning as defined by Hoggan (2016). Students changed their assumptions about scholarly debate (Worldview), valued their own purpose in a research endeavor (Self), and gained an appreciation for asking questions (Behavior) (Hoggan, 2016, Figure 1).

This study included a small sample of a select set of students, in a rather unusual pedagogical setting. All of these conditions could have contributed to our findings. Our study was not able to determine whether they are strictly necessary to repeat the findings we reported here, partially responsible, or only incidental. It will be worthwhile, although not straight-forward, to investigate the

relative importance of these factors in shaping student learning in a co-taught course. For example, how does co-teaching scale to larger classes? Do benefits diminish with a decreasing student-faculty ratio, or remain constant?

We have argued that co-teaching can substantially change how students view their teachers. It would, therefore, be interesting to more closely examine how this changing view could be best harnessed to support learning in a more personal, individualized manner.

Conclusion

We have argued that co-teaching an interdisciplinary course offers a range of important benefits to both students and instructors. We provided support for previously published gains and also added a new positive outcome. We are obviously convinced that co-teaching is one of the best and most rewarding of teaching approaches—for both students and instructors. However, our own experiences and existing literature taught us that implementing a co-taught course is not straightforward or easy. In discussing some of the barriers and issues below, we do not want to discourage individual instructors or institutions from considering co-teaching. Rather, our intent is to recognize these obstacles and show that they can be overcome with careful planning and extensive support, and that the overall benefit of co-teaching still outweighs the difficulties.

Barriers to co-teaching begin with institutional regulations and practices, especially when departmental boundaries play a role (Bass et al., 2023). It typically requires much more effort to set up a new course that will be offered to students from at least two departments. To start, approvals need to be received from all involved departments and possibly several other, higher, administrative units, such as curriculum committees. The administration of the course can also become more complex since student numbers and records must be aligned between departments, which is not usually part of the regular administrative process. We found that support from our departments was instrumental. Having student advisors or administrators who are willing to communicate and coordinate across departmental or institutional borders, and who are not afraid to deal with new and unusual requests or processes, is essential. Ensuring this type of support should be an early step in the planning process for a co-taught course.

It can be difficult as well to achieve a sufficiently large class size to run the course. In our case, the course is not required for programs in either department and, due to its course code, appears at the bottom of course listings. This means that many students are not aware of this course offering. Creating specific announcements on a learning management system, in cognate courses, or at student events can help increase students' awareness of the offering. Additionally, both the characteristics we highlighted here as advantages—co-teaching and interdisciplinarity—are new and unfamiliar to many students and may not attract a large part of the student body. We hope that with an increasing proportion of students having taken such our course—and hopefully more co-taught courses being offered in the future—the message that it

is a worthwhile and valuable experience will spread through the student community.

Probably more difficult to solve is the issue of teaching load. Despite preparing and holding all lectures together and completing all marking as a team, instructors might receive only half the teaching credit that is given for a solo-taught course. Even for tenured or permanent faculty, this calculation of workload imposes a disadvantage; for a sessional or graduate student instructor, the reduced teaching recognition could make it difficult to achieve a sufficiently large teaching load to make a living or to retain their work status at their institution (Morelock et al., 2017). Such workload issues are only solvable with broad and sustained institutional support. Our hope is that the increasing evidence of the effectiveness and impact of co-teaching on student learning, as well as on teacher training (e.g., Andrews et al., 2016; Jarvis and Kariuki, 2017; Dubek and Doyle-Jones, 2021), will eventually lead to stronger administrative support.

The experiences we have described in this paper stem from one course that came about under specific circumstances. As evidenced by the literature we have referred to here, the advantages of co-teaching can be extended to a range of settings, from small to large classes, introductory to upper-year courses, and across disciplines and teaching contexts.

If co-teaching is not an option at an institution or for an individual instructor, we believe that some of the benefits we outlined above can be achieved in solo-taught courses as well. Surely, acknowledging the limits to one's knowledge while teaching, and discussing what such limits imply for the field of study, will help manage student expectations regardless of the teaching approach. If done properly, students could see this as an invitation to talk to their instructor about their questions and not view instructors as the sole and infallible source of one-way information.

Inviting guest lecturers could further assist in addressing limits of knowledge. This option can also provide some of the benefits related to seeing scholars interact with each other. To achieve these goals, some familiarity between instructor and invitee, or at least some careful planning ahead of the visit, will be essential.

With this investigation, we have contributed more evidence showing that co-teaching is not only an effective approach to teach interdisciplinary and complex topics, but also a way to influence students' perception of scholarly interactions and of their own roles as scholars. We hope that the increasing amount of evidence for the success of co-teaching will lead institutions to reduce barriers and increase support for this exciting, valuable, and impactful teaching approach.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

Surveys and methodology were approved by the University of Toronto Human Research Ethics Unit (Protocol # 00042107). The

study was conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

CR: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing, Funding acquisition. CD-M: Data curation, Formal analysis, Writing – review & editing, Investigation. MC: Formal analysis, Investigation, Writing – original draft, Writing – review & editing, Funding acquisition.

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References

- Anderson, R. S., and Speck, B. W. (1998). 'Oh what a difference a team makes': Why team teaching makes a difference. *Teach. Teach. Educ.* 14, 671–686. doi: 10.1016/S0742-051X(98)00021-3
- Andrews, T. C., Conaway, E. P., Zhao, J., and Dolan, E. L. (2016). Colleagues as change agents: How department networks and opinion leaders influence teaching at a single research university. *CBE Life Sci. Educ.* 15:ar15. doi: 10.1187/cbe.15-08-0170
- Bandura, A. (1977). *Social Learning Theory*. Englewood Cliffs: Prentice Hall.
- Barahona, M. (2017). Exploring models of team teaching in initial foreign/second language teacher education: A study in situated collaboration. *Aust. J. Teach. Educ.* 42, 144–161. doi: 10.14221/ajte.2017v42n12.9
- Bass, M., Dompierre, K. B., and McAlister, M. (2023). Creating transformative interdisciplinary learning opportunities for college students. *J. Transform. Educ.* 21, 118–137. doi: 10.1177/15413446211066934
- Batz, Z., Olsen, B. J., Dumont, J., Dastoor, F., and Smith, M. K. (2015). Helping struggling students in introductory biology: a peer-tutoring approach that improves performance, perception, and retention. *CBE Life Sci. Educ.* 14:ar16. doi: 10.1187/cbe.14-08-0120
- Biggs, J. B. (2003). *Teaching for Quality Learning at University*. Maidenhead: Open University Press.
- Biggs, J. B., and Collis, K. F. (1982). *Evaluating the Quality of Learning: The SOLO Taxonomy, Structure of the Observed Learning Outcome*. London: Academic Press.
- Bonnard, C. (2020). What employability for higher education students? *J. Educ. Work.* 33, 425–455. doi: 10.1080/13639080.2020.1842866
- Brooks, R., Gupta, A., Jayadeva, S., and Abrahams, J. (2020). Students' views about the purpose of higher education: a comparative analysis of six European countries. *High. Educ. Res. Dev.* 29, 167–172.
- Buckingham, L. R., López-Hernández, A., and Strotmann, B. (2021). Learning by comparison: The benefits of co-teaching for university professors' professional development. *Front. Educ.* 6:776991. doi: 10.3389/feduc.2021.776991
- Burns, V. F., and Mintzberg, S. (2019). Co-teaching as teacher training: experiential accounts of two doctoral students. *Coll. Teach.* 67, 94–99. doi: 10.1080/87567555.2018.1558169
- Carpenter, D. M., Crawford, L., and Walden, R. (2007). Testing the efficacy of team teaching. *Learn. Environ. Res.* 10, 53–65. doi: 10.1007/s10984-007-9019-y
- Chanmugam, A., and Gerlach, B. (2013). A co-teaching model for developing future educators' teaching effectiveness. *Int. J. Teach. Learn. Higher Educ.* 25, 110–117.
- Choi, B. C. K., and Pak, A. W. (2006). Multidisciplinarity, interdisciplinarity and transdisciplinarity in health research, services, education and policy: 1. definitions, objectives, and evidence of effectiveness. *Clin. Invest. Med.* 29, 351–364. doi: 10.25011/cim.v31i1.3140
- Cleveland, L. M., Olimpo, J. T., and DeChenne-Peters, S. E. (2017). Investigating the relationship between instructors' use of active-learning strategies and students' conceptual understanding and affective changes in introductory biology: a comparison of two active-learning environments. *CBE Life Sci. Educ.* 16:ar19. doi: 10.1187/cbe.16-06-0181
- Common Core Standards Initiative (2020). *Common core state standards*. Available online at: www.corestandards.org (Accessed October 29, 2024).
- Cook, N. D. (2015). "The Columbian Exchange," in *The Cambridge World History Volume 6: The Construction of a Global World, 1400–1800 CE, Part 2: Patterns of Change*, eds. J.H. Bentley, S. Subrahmanyam, and M.E. Wiesner-Hanks (Cambridge: Cambridge University Press), 103–134.

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Supplementary material

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- Cordie, L. A., Brecke, T., Lin, X., and Wooten, M. C. (2020). Co-teaching in higher education: mentoring as faculty development. *Int. J. Teach. Learn. Higher Educ.* 32, 149–158.
- Cowan, M. (2021). *Transferrable skills are a byproduct, not the point, of a university education*. University Affairs. Available online at: <https://www.universityaffairs.ca/opinion/in-my-opinion/transferrable-skills-are-a-byproduct-not-the-point-of-a-university-education/> (Accessed October 29, 2024).
- Crosby, A. W. (2003). *The Columbian Exchange: Biological and Cultural Consequences of 1492*. Westport: Praeger Publishers.
- Crow, J., and Smith, L. (2005). Co-teaching in higher education: Reflective conversation on shared experience as continued professional development for lecturers and health and social care students. *Reflect. Pract.* 6, 491–506. doi: 10.1080/14623940500300582
- Danisch, R. (2021). *The problem with online learning? It doesn't teach people to think*. The Conversation. Available online at: <https://theconversation.com/the-problem-with-online-learning-it-doesnt-teach-people-to-think-161795> (Accessed July 5, 2021).
- de Welde, K., Foote, N., Hayford, M., and Rosenthal, M. (2014). Team teaching 'gender perspectives': a reflection on feminist pedagogy in the interdisciplinary classroom. *Fem. Teach.* 23, 105–125. doi: 10.5406/femteacher.23.2.0105
- Deighton, L. C. (1971). *The Encyclopedia of Education*. New York: Macmillan.
- Dubek, M., and Doyle-Jones, C. (2021). Faculty co-teaching with their teacher candidates in the field: co-planning, co-instructing, and co-reflecting for STEM education teacher preparation. *Teach. Educ.* 54, 445–465. doi: 10.1080/08878730.2021.1930310
- Fam, D., Clarke, E., Freeth, R., Derwort, P., Klaniecki, K., Kater-Wettstädt, L., et al. (2020). Interdisciplinary and transdisciplinary research and practice: balancing expectations of the 'old' academy with the future model of universities as 'problem solvers'. *Higher Educ. Q.* 74, 19–34. doi: 10.1111/hequ.12225
- Fawcett, J. (2013). Thoughts about multidisciplinary, interdisciplinary, and transdisciplinary research. *Nurs. Sci. Q.* 26, 376–379. doi: 10.1177/0894318413500408
- Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., et al. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proc. Natl. Acad. Sci. USA* 111, 8410–8415. doi: 10.1073/pnas.1319030111
- Haag, K., Pickett, S. B., Trujillo, G., and Andrews, T. C. (2023). Co-teaching in undergraduate stem education: A lever for pedagogical change toward evidence-based teaching? *CBE Life Sci. Educ.* 22:es1. doi: 10.1187/cbe.22-08-0169
- Heck, T. W., and Bacharach, N. (2015). A better model for student teaching. *Educ. Leadersh.* 73, 24–29.
- Helms, M. M., Alvis, J. M., and Willis, M. (2005). Planning and implementing shared teaching: an MBA team-teaching case study. *J. Educ. Business* 81, 29–34. doi: 10.3200/JOEB.81.1.29-34
- Hoggan, C. D. (2016). Transformative learning as a metatheory. *Adult Educ. Q.* 66, 57–75. doi: 10.1177/0741713615611216
- Horsburgh, J., and Ippolito, K. (2018). A skill to be worked at: Using social learning theory to explore the process of learning from role models in clinical settings. *BMC Med. Educ.* 18:156. doi: 10.1186/s12909-018-1251-x
- Jarvis, D. H., and Kariuki, M. (2017). *Co-teaching in Higher Education: From Theory to Co-Practice*. Toronto: University of Toronto Press. doi: 10.3138/9781487514228
- King, B., Dinsmore, C., Thornton, A., Beyer, W., Akiva, K., and Dalton, C. J. (2019). multidisciplinary team-based model for faculty supports in online learning. *Collect. Ess. Learn. Teach.* 12, 127–138. doi: 10.22329/celt.v12i0.5382
- Krometis, L. H., Clark, E. P., Gonzalez, V., and Leslie, M. E. (2011). The 'death' of disciplines: Development of a team-taught course to provide an interdisciplinary perspective for first-year students. *Coll. Teach.* 59, 73–78. doi: 10.1080/87567555.2010.538765
- Liebel, G., Burden, H., and Helda, R. (2017). For free: continuity and change by team teaching. *Teach. Higher Educ.* 22, 1–16. doi: 10.1080/13562517.2016.1221811
- Lock, J., Rainsbury, J., Clancy, T., Rosenau, P., and Ferreira, C. (2018). Influence of co-teaching on undergraduate student learning: a mixed-methods study in nursing. *Teach. Learn. Inq.* 6, 38–51. doi: 10.20343/teachlearningqu.6.1.5
- Malachowski, C. C., Martin, M. M., and Vallade, J. I. (2013). An examination of students' adaptation, aggression, and apprehension traits with their instructional feedback orientations. *Commun. Educ.* 62, 127–147. doi: 10.1080/03634523.2012.748208
- Mann, C. C. (2019). "Columbian exchange," in *The Routledge Handbook to the History and Society of the Americas*, eds. O. Kaltmeier, J. Raab, M.S. Foley, A. Nash, S. Rinke, and M. Rufer (Abingdon: Routledge), 67–74. doi: 10.4324/9781351138703-7
- Miller, T., Baird, T., Littlefield, C., Kofinas, G., Chapin, F., and Redman, C. (2008). Epistemological pluralism: reorganizing interdisciplinary research. *Ecol. Soc.* 13:46. doi: 10.5751/ES-02671-130246
- Morelock, J., Lester, M., Klopfer, M., Jardon, A., Mullins, R., Nicholas, E., et al. (2017). Power, perceptions, and relationships: a model of co-teaching in higher education. *Coll. Teach.* 65, 1–10. doi: 10.1080/87567555.2017.1336610
- Nandan, M., and London, M. (2013). Interdisciplinary professional education. Training college students for collaborative social change. *Educ. Train.* 55, 815–835. doi: 10.1108/ET-06-2013-0078
- Nápoles, J. (2024). Co-teaching: a review of the literature. *Update: Appl. Res. Music Educ.* 43, 34–40. doi: 10.1177/87551233231226131
- Oh, K., Murawski, W., and Nussli, N. (2017). An international immersion into co-teaching: a wake-up call for teacher candidates in general and special education. *J. Spec. Educ. Apprent.* 6, 1–20. doi: 10.58729/2167-3454.1057
- Petersen, C., Baepier, P., Beitz, A., Ching, P., Gorman, K., Neudauer, C., et al. (2020). The tyranny of content: "Content coverage" as a barrier to evidence-based teaching approaches and ways to overcome it. *CBE Life Sci. Educ.* 19:ar17. doi: 10.1187/cbe.19-04-0079
- Posit team (2025). *RStudio: Integrated Development Environment for R*. Posit Software, PBC, Boston, MA. Available online at: <http://www.posit.co/>
- Renshaw, S., and Valiquette, R. (2017). "Complex collaborations: co-creating deep interdisciplinarity for undergraduates," in *Co-Teaching in Higher Education: From Theory to Co-Practice*, eds. D. Jarvis and M. Kariuki (Toronto: University of Toronto Press), 31–62. doi: 10.3138/9781487514228-005
- Rooks, R. N., Scandlyn, J., Pelowich, K., and Lor, S. (2022). Co-teaching two interdisciplinary courses in higher education. *Int. J. Scholarsh. Teach. Learn.* 16:5. doi: 10.20429/ijstol.2022.160208
- Self, J. A., and Baek, J. S. (2017). Interdisciplinarity in design education: understanding the undergraduate student experience. *Int. J. Technol. Des. Educ.* 27, 459–480. doi: 10.1007/s10798-016-9355-2
- Sheriff LeVan, K., and King, M. (2015). *Team teaching: active learning practice for teachers*. The Teaching Professor. Available online at: <https://www.teachingprofessor.com/topics/teaching-strategies/active-learning/team-teaching-active-learning-practice-for-teachers/> (Accessed October 29, 2024).
- Shibley, I. A. (2006). Interdisciplinary team teaching: negotiating pedagogical differences. *Coll. Teach.* 54, 271–274. doi: 10.3200/CTCH.54.3.271-274
- Smith, K. K., and Winn, V. G. (2017). Co-teaching in the college classroom. *Teach. Educ.* 28, 435–448. doi: 10.1080/10476210.2017.1325863
- Stobaugh, R., and Everson, K. (2019). Student teacher engagement in co-teaching strategies. *Educ. Renaissance* 8, 30–47. doi: 10.33499/edren.v8i1.137
- Stork, E., and Hartley, N. T. (2009). Classroom incivilities: students' perceptions about professors' behaviors. *Contemp. Issues Educ. Res.* 2, 13–24. doi: 10.19030/cier.v2i4.1066
- Styers, M. L., Van Zandt, P. A., and Hayden, K. L. (2018). Active learning in flipped life science courses promotes development of critical thinking skills. *CBE Life Sci. Educ.* 17:ar39. doi: 10.1187/cbe.16-11-0332
- Trinidad, J. E., Raz, M. D., and Magsalin, I. M. (2021). 'More than professional skills': student perspectives on higher education's purpose. *Teach. Higher Educ.* 28, 1380–1394. doi: 10.1080/13562517.2021.1891043
- Vembye, M. H., Weiss, F., and Hamilton, B. H. (2024). The effects of co-teaching and related collaborative models of instruction on student achievement: a systematic review and meta-analysis. *Rev. Educ. Res.* 94, 376–422. doi: 10.3102/00346543231186588
- Vickrey, T., Rosploch, K., Rahmanian, R., Pilarz, M., and Stains, M. (2015). research-based implementation of peer instruction: a literature review. *CBE Life Sci. Educ.* 14:es3. doi: 10.1187/cbe.14-11-0198
- Walters, K., and Mistra, J. (2013). Bringing collaborative teaching into doctoral programs: faculty and graduate student co-teaching as experiential training. *Am. Sociol.* 44, 292–301. doi: 10.1007/s12108-013-9185-6
- Yanamandram, V., and Noble, G. (2006). Student experiences and perceptions of team-teaching in a large undergraduate class. *J. Univ. Teach. Learn. Pract.* 3, 49–66. doi: 10.53761/1.3.1.6
- Zach, S. (2020). Co-teaching—an approach for enhancing teaching-learning collaboration in physical education teacher education (Pete). *J. Phys. Educ. Sport* 20, 1402–1407.
- Zach, S., and Avugos, S. (2024). Co-Teaching in higher education: implications for teaching, learning, engagement, and satisfaction. *Front. Sports Act. Living* 6:1424101. doi: 10.3389/fspor.2024.1424101