CASE STUDY

Students priming students for success: Students as partners in development of pre-lecture resources for introductory genetics

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ABSTRACT

Introductory science courses can be a struggle for instructors and students not only because of the challenging nature of the material, but also due to differences in the background knowledge of students. Provision of pre-lecture resources reviewing or introducing key concepts is recommended to support diverse students. In this paper, we describe the iterative design, implementation, and assessment of pre-lecture PRIMERs in a large, introductory genetics course. The development of PRIMERs was conceived, driven, and performed by a student-staff team. Data over 2 years demonstrate that most students considered that PRIMERs supported their learning of the lecture material. Student comments revealed that they found the summaries and practice problems useful, and that they used PRIMERs both as lecture preparation and examination review resources. These results suggest that the students-as-partners model is an effective way to create and refine course resources.

KEYWORDS

students as partners, genetics, pre-lecture materials, reflections, large classes

Large introductory class sizes are challenging for students and instructors for many reasons, including the logistics of interaction, engagement, and student learning support due to high student-to-instructor ratios (Carbone & Greenberg, 1998; Mulryan-Kyne, 2010). This is further complicated by the fact that students enter these courses with differing levels of knowledge due to variations in secondary school coverage and students' personal circumstances (Salehi et al., 2019). The heterogeneity of students' pre-university preparation in the sciences can have a significant effect on their learning and achievement in introductory courses with severe downstream effects on their university outcome and future career (e.g., retention at university or in the sciences, choice of and success in their programs, access to professional or graduate schools) (Salehi et al., 2019). One way to address differential student background is pre-lecture

review resources to ensure that students are primed for learning new material (Kinsella et al., 2017; Seery & Donnelly, 2012).

LITERATURE REVIEW

Pre-lecture materials

In STEM higher education, pre-lecture learning is used to introduce students to a subject or activate their prior knowledge (Kinsella et al., 2017; Moravec et al., 2010), thus reducing cognitive load during classroom activities (Hadie et al., 2019; Seery & Donnelly, 2012). Pre-lecture materials can range from review-type resources meant to ensure that all students have the required background knowledge and terminology for the course material to be presented (as in the case we describe) through providing new course material ahead of the lecture to allow class time to be spent doing problem solving and active learning in a flipped class (Kinsella et al., 2017; Seery & Donnelly, 2012). Studies have shown that providing students with pre-lecture material can predict academic performance (Gammerdinger & Kocher, 2018; Hadie et al., 2019; Moravec et al., 2010; Pulukuri & Abrams, 2021; Seery & Donnelly, 2012) and decrease student stress (Robertson et al., 2020).

Instructors commonly assign textbook readings as pre-lecture material (Gammerdinger & Kocher, 2018). However, textbooks are unaffordable for many students (U.S. Government Accountability Office, 2013) and often not read (Clump et al., 2004; Gammerdinger & Kocher, 2018). Reasons provided by students for not reading textbooks include time constraints, absence of textbook material on exams, and opaque writing style (Berry et al., 2010; Gammerdinger & Kocher, 2018).

An alternative to textbooks for pre-lecture learning is customized instructional materials designed to introduce core concepts for the course. These resources have been shown to minimize difference in grades between students with and without sufficient background knowledge (Seery & Donnelly, 2012) and can lead to more active learner engagement in large courses (Kinsella et al., 2017). Pre-lecture resources can include targeted multimedia learning modules that allow for students to learn more effectively and retain concepts (Vazquez & Chiang, 2016). Customized pre-lecture resources are also more likely to include terminology used in the course, reducing confusion for students (Gammerdinger & Kocher, 2018). Course instructors can construct pre-lecture learning modules with open educational resources. Defined as free education materials accessible by users for non-commercial "consultation, use, and adaptation" (UNESCO, 2002, p. 24), open educational resources can achieve similar learning outcomes as textbooks (Hilton, 2016; 2020).

Students as partners

Students as partners (SaP) describes a framework for students and instructors to work together to create beneficial learning environments. It supports "a collaborative, reciprocal process through which all participants have the opportunity to contribute equally, although not necessarily in the same ways, to curricular or pedagogical conceptualization, decision making, implementation, investigation, or analysis" (Cook-Sather et al., 2014, pp. 6–7). SaP is generally viewed positively by both students and instructors. Cited benefits to students include increased sense of belonging, metacognitive learning, motivation for learning, and self-efficacy, while

instructors have reported developing better teaching/curriculum resources and teaching practices (Cook-Sather et al., 2014; Curran, 2017; Werder & Ottis, 2010; Hanna-Benson et al., 2020; Mercer-Mapstone et al., 2017; Petrescu et al., 2021).

There have been multiple calls for increased SaP in the co-creation of curriculum materials and educational resources (Bovill et al., 2011; Felten et al., 2019; Healey et al., 2014). Co-creation work challenges the traditional student-instructor power dynamics and institutional structures (Bovill et al., 2016; Lubicz-Nawrocka, 2017; 2018), which may explain why it is more popular in theory than in practice (Lubicz-Nawrocka, 2018). Despite these obstacles, students and instructors have reported benefits such as increased feelings of shared responsibility, respect, and trust; active learning experiences; and opportunities for professional development (Ahmad et al., 2017; Goff & Knorr, 2018; Lubicz-Nawrocka, 2018).

Purpose

Building upon the recognized benefits of offering pre-lecture materials, we developed custom pre-lecture resources for an introductory genetics course. Since these offer students additional background knowledge in preparation for lectures presenting complex concepts, we named them PRIMERs. Further, we present the use of the SaP framework with student partners performing various roles in the ideation, creation, assessment, and revision of PRIMERs. We discuss our work as a form of action research, in which the resource was developed and improved through iterative cycles of assessment and revision by our student-instructor team (Crane & Richardson, 2000; Efron & Ravid, 2019). Through reflection on the entire process, we provide recommendations for other groups interested in using SaP-driven action research to develop student-centred course resources.

METHODOLOGY

Context

This project supported a very large introductory genetics course (~700 students/year) at a research-intensive university in eastern Canada.

Assessment of student perceptions of PRIMERs

Student perceptions of PRIMERs were collected as part of anonymous online surveys of introductory genetics active learning tools (in 2020) and of remote learning tools (in 2021) (Figure 1). Survey data were collected mid-term in 2020 due to COVID-19 course interruptions (*n*=697/697 students) and at the end of the term in 2021 (*n*=473/757 students).

Written comments were imported into qualitative data analysis software (MAXQDA 2020 or 2022) for coding. Coding was performed using qualitative content analysis, using a combination of a pre-established coding frame and the development of new codes, then themes, through inductive data engagement (Schreier, 2012). Initial coding focused on comments relating to the pros and cons of the PRIMERs, followed by more detailed analysis of feedback to extract more specific themes.

Assessment of the SaP process in PRIMER design and assessment

To investigate our use of SaP to develop, assess, and improve PRIMERs, we inductively coded a combination of individual written reflections and extracts from the writing team's minutes and emails. The writing team consists of the instructor, a graduate student, and three undergraduate students involved in course revision.

RESULTS

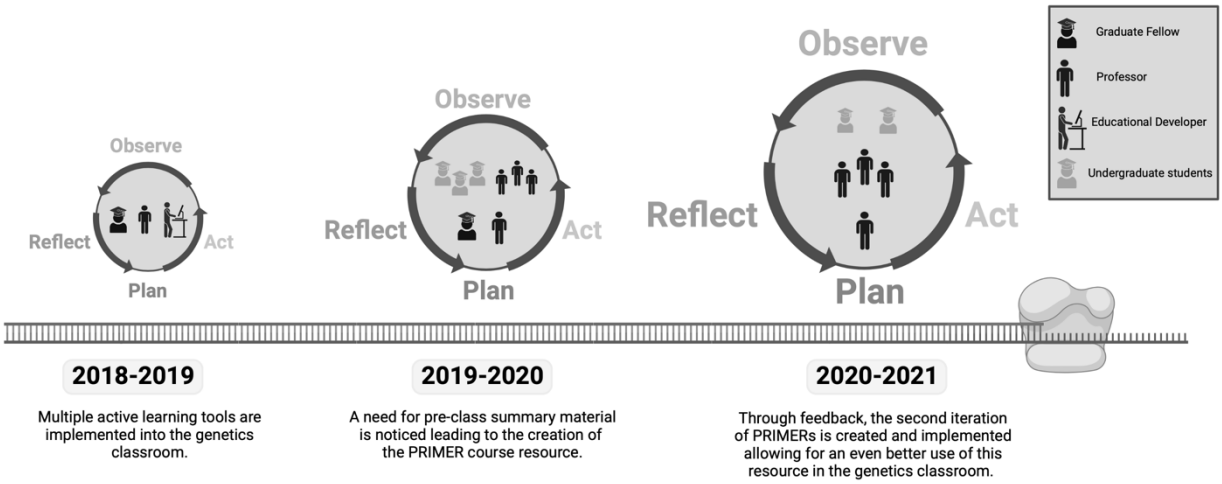
An ecosystem of SaP in the creation and assessment of PRIMERs

In 2018, the instructor rejoined introductory genetics and decided upon an action research approach to make multiple updates to the course to increase student engagement and learning. To do this, she liaised with an educational developer from the nascent Office of Science Education and took advantage of multiple initiatives to engage graduate and undergraduate students as partners in course re-design and the scholarship of teaching and learning (SoTL). Three new SaP opportunities emerged from this work with the Office of Science Education. First, a pilot program was launched of a graduate student teaching development fellowship. As part of the program, graduate student fellows were assigned to courses for up to 2 years (90 hours per term for 4 terms with pay equivalent to being a teaching assistant) to assist in course (re-) design and assessment. Second, a course design stream was added to an undergraduate student award for peer-mentoring (Petrescu et al., 2021). Named Tomlinson Engagement Award for CHange (TEACH) fellows, recipients of the new award dedicate 25–30 hours per term to building course resources. Finally, two new one-term courses were created: FSCI 396 and 397 – Research Project in Science Teaching and Learning 1 and 2. These independent studies research courses give science students the opportunity to work on SoTL projects with staff (Western et al., 2020).

Several active learning strategies were implemented into introductory genetics in Winter 2019 by the instructor, the graduate student partner, and an educational developer. A survey was performed to collect information on student use and perceptions of these activities (Figure 1, 2018–2019 cycle). An undergraduate research project student (undergraduate [UG]1) performed detailed analysis of this data in Fall 2019. Realizing a joint desire to provide students with background material for the course, the instructor, graduate student, and UG1 partnered in Winter 2020 to design, write, and implement the PRIMERs pre-lecture summary and course resource guides that term. PRIMERs production was facilitated by the identification of course-relevant open educational resources in Fall 2019 by an undergraduate course design assistant (UG2). Re-alignment of course learning objectives was facilitated by another research student (UG3) in Winter 2020. In-class polling and a midterm survey were used to collect student feedback on the first iteration of PRIMERs, and preliminary analysis was conducted by UG1 in Winter 2020 (Figure 1, 2019–2020 cycle). In Fall 2020, a third research project student (UG4) performed a detailed analysis of the Winter 2020 data, and UG2 returned for a second course design assistant term. Based on the feedback provided by UG4 on the first iteration, the 2021 PRIMERs were updated, shortened, and embedded at the beginning of the lecture slide decks by the instructor and UG2 in collaboration with other course instructors (Figure 1, 2020–2021 cycle). Student survey data collected at the end of the 2021 course were analyzed by UG1 and UG4 during the writing of this collaborative paper. All this work was performed within the SaP framework, with students and the instructor collaborating on goal setting, design, analysis,

assessment, revision, and communication of results. This includes the writing of this paper by the instructor, the graduate student, and UG1, 2, and 4.

Figure 1. Diagram summarizing SaP activities surrounding the creation and assessment of PRIMERs over 3 academic years



The iterative cycles of PRIMER design, implementation, and assessment are reflected in a collaborative action research framework of plan, act, observe, reflect, and repeat.

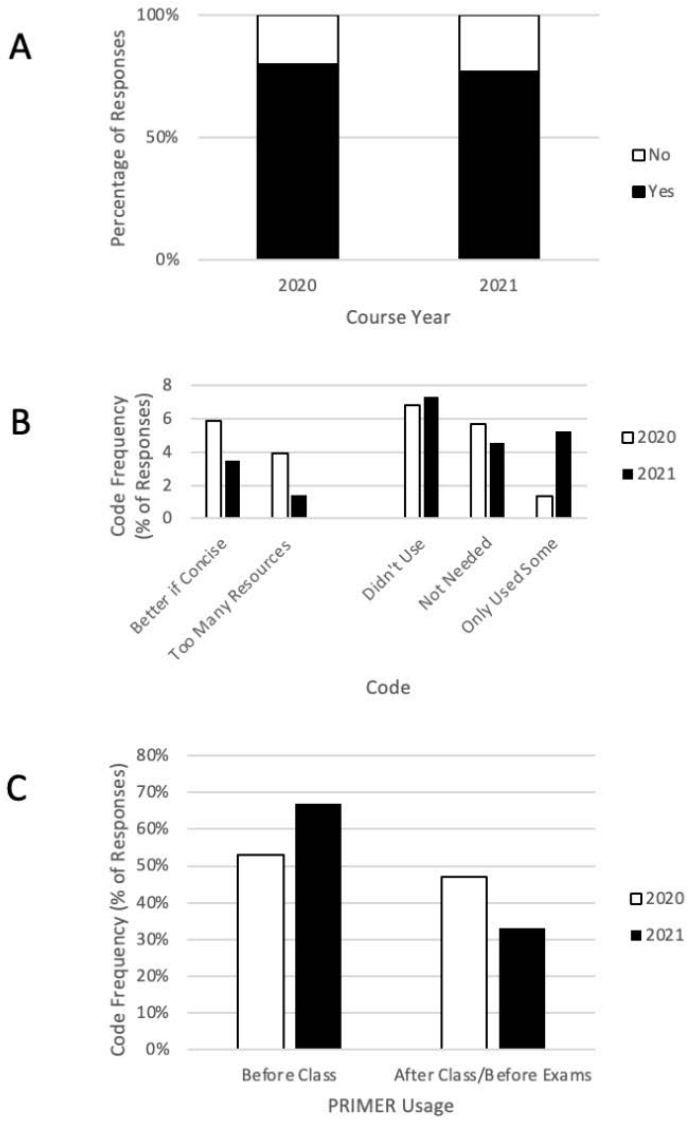
Description of PRIMERs

PRIMERs were designed to be a one-stop shop for introductory genetics students, containing both pre-lecture materials and a guide to relevant course resources. There were 18 PRIMERs aligned with different course modules. Each PRIMER contains (a) course learning objectives and outcomes, (b) pre-lecture background summaries, (c) textbook readings and assigned practice problems, (d) links to online open educational resources, and (e) a "Genetics in the News" section to tie the material to the real world.

PRIMERs supported learning for the majority of genetics students

To assess student opinions towards PRIMERs in the 2020 semester, we asked them, "Did you find that PRIMERs supported your learning of the lecture material [yes/no]?" All students in the class (697) responded, and 80% answered yes (Figure 2A). Space for written comments allowed students to elaborate on their answers, which were coded for themes and sub-themes (Table 1). Of the 511 students who commented, the majority (74%) explained that PRIMERs *supported learning* in ways ranging from allowing familiarization with concepts before class to summarizing lecture content, simplifying difficult concepts, and explaining genetics jargon. A smaller number (5%) explained that PRIMERs *did not support learning* because there was not enough time to use them, students already knew the material, PRIMERs lacked the needed information, and there were an overwhelming number of resources in the genetics class. Approximately 11% provided mixed comments, while 10% explained that they never used PRIMERs and could not comment on their usefulness.

Figure 2. Student survey responses in 2020 and 2021



(A) Percentage of student yes/no responses to "Did you find that the PRIMERs supported your learning of the lecture material?" (2020, n=697/697; 2021, n=473/757). (B), (C) Frequency of codes obtained through inductive coding of written comments received from introductory genetics students. (2020, n=511/697; 2021, n=214/757

Table 1. Thematic analysis of written comments answering "Did you find that the PRIMERs supported your learning of the lecture material? [Yes/No] Please elaborate in the space below" from introductory genetics surveys in 2020 and 2021

MAJOR THEMES	PERCENT RESPONDENTS		SUB-THEMES	EXAMPLE STUDENT COMMENTS
	2020	2021		
Supported Learning	74% (n=366)	60% (n=125)	Allowed familiarity with concepts before class	"The PRIMERs allowed me to come to class knowing the necessary background material for the lecture" (2020)

MAJOR THEMES	PERCENT RESPONDENTS		SUB-THEMES	EXAMPLE STUDENT COMMENTS
				"The PRIMERs were a nice refresher of concepts that I had forgotten from previous classes" (2021)
			Good summary of the lecture	"The PRIMERs were a good concise summary of what has been learned in each topic" (2020) "Provide a clear and concise summary of the key points of the course materials, which was quite helpful" (2021)
			Helpful post-lecture reference for review and catch-up	"Super helpful for review" (2020) "If there was a concept I didn't understand during the lecture I would go back to the primers to help me better understand" (2021)
			Simplified more difficult concepts	"It simplified the more difficult concepts" (2020) "The PRIMERs helped clarify some basic information such as terminology and basic concepts that may have been forgotten" (2021)
Did Not Support Learning	5% (n=25)	14% (n=30)	Did not have time	"I did them at the beginning but then my schedule got too busy and couldn't find time to look at them consistently before every class" (2020) "The primers are very good, except I have neglected to read them more and more, as my other classes' workload has increased" (2021)
			Already knew this material	"Learning the material through the lecture already comes smoothly enough" (2020) "I felt like I knew the primers' content already" (2021)
			Not the right information in the PRIMERs	"I'd rather have resources that are summary and review tools, but primers don't do that because they miss a lot of the more complicated concepts" (2020) "Some primers were too simply written when compared to lecture material" (2021)
			Overwhelming number of resources	"I find it very hard to keep up with all the new resources being posted in the class. Sometimes too many resources, if not communicated effectively, could be worse" (2020) "Incredibly overwhelmed by the amount of resources in this course" (2021)
Did Not Use PRIMERs	10% (n=50)	9% (n=19)		"I didn't really use PRIMERs, I think that the class material was enough" (2020) "They weren't something I really spent time looking over" (2021)
Mixed Remarks About PRIMERs	11% (n=57)	17% (n=35)		"Gives a good summary of the lectures. Would like it if there were harder problem examples so we could see how to work through them properly" (2020) "Sometimes they were helpful. Sometimes they were excessively long and unhelpful" (2021)

Coding for use cases revealed that 53% of the students who mentioned timing used PRIMERs as a pre-lecture resource, whereas the other 47% used them as a review tool (Figure

2C). This was also reflected in the timing of PRIMER downloads on our learning management system, which showed high access numbers both before the relevant lectures and ahead of class assessments (data not shown). This raised the question of whether students were accessing PRIMERs too late to use before class since some students mentioned the "overwhelming" amount of course resources (e.g., "I find it very hard to keep up with all the new resources being posted").

Embedding PRIMERs into slide decks increases use pre-lecture

Based on our analysis of the 2020 student comments, we decided to move the PRIMERs from a set of stand-alone documents into the course slide decks ahead of the relevant lectures. This reduced the number of documents students had to access and clarified the corresponding PRIMER for each lecture, hopefully leading to less confusion and more usage pre-lecture. Further, in response to comments emphasizing the importance of concision and the lack of time students had to engage with optional course resources, we made the PRIMER summaries more succinct. After implementing these changes, we ran an end-of-term survey in Winter 2021 to see if there was a change in student perceptions of PRIMERs.

In the 2021 semester, while fewer students answered the survey (62% of the class, n=473/757 versus 100% of 697 in 2020), a similar percentage of students answered yes that PRIMERs supported their learning (77% in 2021 vs 80% in 2020; Figure 2A). When 2021 written comments were analyzed for sentiment, similar reasons for both supporting student learning and not supporting learning were identified as in 2020 (Table 1), despite the lower percentage of students providing comments in 2021 (n=214/757 students).

When we compared the proportion of student comments stating that there were too many resources in the course or that PRIMERs should be more concise between years, we found that both concerns decreased in 2021 (Figure 2B). To see the effect of moving PRIMERs into the slide deck, we considered comments relating to PRIMER usage timing and frequency. With respect to comments on timing, we found that the proportion of students using PRIMERs before class rose to 67% in 2021 from 53% in 2020 (Figure 2C). Finally, we found that more students commented that they *only used some* PRIMERS and fewer students who felt PRIMERs *were not needed* (Figure 2B). Both are consistent with increased student engagement with PRIMERs due to their inclusion at the start of lecture slide decks. Specifically, these results could reflect that more students reviewed the PRIMERs to decide if they felt they were useful for them for that module.

DISCUSSION

What genetics students want in a pre-lecture resource

Our results showed that students agreed that the PRIMER pre-lecture resources supported their learning since they helped them learn background information, provided familiarity with content before lectures, and were a good review tool. Further, we found that, despite being student self-reported data, surveys were an effective way to identify the strengths and weaknesses of course resources and that acting on the suggestions of students led to improvements. Since our data collection was anonymous, we were unable to compare students' perceptions of PRIMERs with student grades. However, studies have shown improved comprehension and performance when

students use pre-lecture resources across many university science courses (e.g., Hadie et al., 2019; Hill et al., 2017; Moravec et al., 2010). The main critiques of PRIMERs were their length and the time needed to engage with them. Previous studies have shown the higher a student's perceived stress, the lower their academic performance (e.g., Varghese et al., 2015). This is an important aspect of any resource and should be kept in mind. Our final observation was that the location of the resource affected how many students accessed it and when. As far as we are aware, this effect has not been studied previously but would be a useful characteristic of course resources to study in the future. Due to the positive reception by students, PRIMERs are still being used in introductory genetics and have been implemented in a second genetics course.

Using SaP facilitates course resource development and benefits partners

In addition to determining student response to the PRIMERs, we examined our experience using SaP to develop and assess course resources. Three themes were identified from a combination of individual written reflections, experience-based extracts from our meeting notes, and group discussions: *benefits*, *challenges*, and *insights*.

Benefits include the overall results of the collaboration—we made something that worked for the course students that came about organically through team synergy. A shared personal gain was the building of new relationships. UG2 noted that "working alongside course professors and graduate teaching assistants allowed me to build relationships that would otherwise not have happened if I was not a partner in this course's development." Benefits to student partners included a view into the teaching process of university instructors, as well as skill development in course design and social science research methods. UG2 reflected that "I also became more resourceful after learning about how to find [open educational resources]; this skill will be especially useful in my future studies." The instructor gained engaged partners in the course redesign process and insight into the student experience, noting that "without [graduate student] and [UG1], [PRIMERs] wouldn't have happened. Without [UG2]'s excellent work screening and recommending appropriate [open educational resources]. . . , we wouldn't have been able to provide those extra resources in the PRIMERs."

Shared challenges included difficulties in team coordination due to the varying time pressures on the team members. Since the work was performed during academic terms, both the students and instructors were working around other academic commitments (e.g., full course load for students and other teaching, research, and/or service commitments for the intstructors). The team was able to mitigate some of these effects through the distribution of tasks based on our availabilities and expertise. Additionally, there were some inconsistent responses from non-team member instructors involved in the course. Although we were lucky enough to have all professors of this team-taught course on board to run surveys and let us implement this classroom tool, they were often busy with other commitments such as their own research and were not able to respond to emails and give us feedback in a timely manner. Other challenges were consciousness of the hierarchy between professors and students and the added instructor workload of collaboration on course materials. Interestingly, the instructor was more mindful of hierarchy than the students, who felt that having a say and being actively involved flattened the power structures. Despite these difficulties, all team members found it a positive experience and would recommend SaP to other students and instructors for course renewal. UG1 stated that "constructing pre-lecture PRIMER material with my colleagues has truly been a moment of pride

and accomplishment for me," while the instructor mentioned that "working with students takes more time, but it is more than worth it to get stuff done and make the course better for students." Together, the benefits and challenges to partners are consistent with those identified in other studies of SaP in both research and curricular development projects (Ahmad et al., 2017; Bovill et al., 2016; Cook-Sather et al., 2014; Curran, 2017; Dickerson et al., 2016; Werder & Ottis, 2010; Hanna-Benson et al., 2020; Lubicz-Nawrocka, 2017; 2018; Mercer-Mapstone et al., 2017).

Insights include the benefits of diversity within a team—a difference of knowledge and experience in one area (e.g., a scientific discipline) does not mean that someone cannot make creative and substantial contributions to a project. The instructor explained: "I learned so much working with everyone—we should never underestimate what others can bring to the table." This echoes other reflective studies on SaP, including multiple co-written essays found in Werder and Ottis (2010). It was also agreed that assessing the PRIMERs as part of an iterative action research design was important to ensure that these pre-lecture resources fulfilled their role and were adapted to meet student needs. UG4 reflected that "the process of understanding how students use resources and their needs was crucial to improving PRIMERs in the way we did between 2020 and 2021." Action research linked to curriculum co-creation is also called for in Bovill et al. (2011). Finally, the multi-year ecosystem of team members, ranging from course instructors to graduate and undergraduate course design assistants to undergraduate pedagogical research students, played a key role in the depth and maintenance of resource development in this project. Not only was there diversity of experience, expertise, and insight within the group, as mentioned above, but team members were able to focus on different roles, carry project information between years, and gain different experiences based on their contributions to the project.

CONCLUSIONS

To conclude, we encourage others to use SaP when designing course materials or revamping a course. As discussed above and in other literature, co-design of course materials has numerous benefits both to students taking the course and to members of the team (Bovill et al., 2011; Hanna-Benson et al., 2016; Lubicz-Nawrocka, 2017; 2018). Within partnerships, it is important to take SaP seriously and to make sure that students are involved in all aspects of the project, including the decision-making process. Further, since courses are constantly updated, it is useful to have team members that span multiple years (students and instructors) as well as to bring in new people to provide fresh perspectives. For multi-instructor courses, it is helpful to bring all instructors into the process to aid communication and buy-in around course changes.

This research project was determined exempt from research ethics certification by the McGill University Research Ethics Board.

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