

A Team-Based Approach to Course Development Involving Undergraduate Researchers

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Abstract

Development of an undergraduate laboratory course can be a challenge, because of the need to balance both logistical and pedagogical considerations. We piloted a team-based approach to developing this type of course and found it to be advantageous as the development process was enhanced by the multiple perspectives and experiences of the team members. Specifically, two faculty members, two undergraduate students (student developers), and a laboratory manager comprised the team which developed an upper-level, advanced cell and molecular biology laboratory course. The involvement of the student developers, in particular, provided a mechanism for assessing the feasibility and effectiveness of course activities and material. The student developers tested and refined experimental modules, reviewed drafts of course materials, and participated in assessment of the first offering of the course. The student developers benefited from an intensive, in-depth bench experience and also a scholarship of teaching and learning (SoTL) research experience. Faculty came away from the process with a much better understanding of the likely capabilities of enrolled students with respect to the course modules. In a second iteration of the team-based approach, we tried modification of the team approach where the team was limited to just the course instructor and one student developer in the development of another laboratory course; however, this approach was less successful. We suggest that involving student developers in a team-based approach to course development can be beneficial for the faculty, the students, and the course itself.

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Supporting Materials: S1. Team-Based Approach to Course Development-Surveys and Rubrics pre- and post-surveys for assessment, and S2. Team-Based Approach to Course Development-Guide to considering this approach

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BACKGROUND

The development of a new course or modification of an existing course for undergraduate students can be a challenging and time-consuming project for a faculty member (1,2,3). To be effective, a course must deliver content in a format that promotes student interest and understanding, provide opportunities for students to apply and develop their knowledge and skills, and include assessment mechanisms that accurately measure student learning, all while operating within the constraints of finite time and budgets. For laboratory-based courses, additional factors to consider include cost and availability of reagents and equipment, complexity of and time requirements for set-up, timing of procedures and their placement within the course schedule, and technical feasibility for undergraduate students.

The process of course development can have a significant impact on the ultimate success of the course. A variety of course development models, involving different participants, have been proposed or used. Examples include:

1. Development of a course solely or largely by a single faculty member (4,5)
2. Collaboration between multiple faculty members, either within a single discipline or as a cross-disciplinary team (6)
3. Collaboration between faculty and support staff with expertise in areas such as pedagogy and instruction design, project management, technology, and graphic design (4,5,7,8,9,10)
4. Collaboration between faculty and students (11)
5. Collaboration between the instructor and enrolled students to make decisions about course structure, content, and grading (11,12)

While the involvement of multiple team members can introduce challenges (such as increased workload, misunderstandings as a result of poor communication, and conflicts over course direction and structure), collaboration between different personnel (or students) can also enrich the development process, as each person contributes his/her own expertise, experiences, and perspective (4,5,10,11).

The University of Wisconsin-Eau Claire is a public liberal arts university serving approximately 10,000 undergraduate students, including approximately 600 Biology and 100 Biochemistry/Molecular Biology majors. In the past, members of the department have used various strategies for course development, in particular the solo and multiple faculty-member models. The need for a revised and updated upper-level, cell and molecular biology laboratory course provided the opportunity to try an approach to course development not previously used in the department. This model involved a course development team, which included two faculty members in the department (a developmental geneticist and a plant molecular biologist) working collaboratively with support staff (the department laboratory manager) and two undergraduate students (who we call the “student developers”) to develop and test modules used in the course. Here we report our experiences using course development teams involving undergraduate students.

THE COURSE

The upper-level, cell and molecular biology laboratory course is taken by students who have an interest in molecular or cell biology, genetics, or biochemistry; many of whom will be pursuing graduate or medical degrees. During the course, enrolled students are introduced to a variety of techniques common in modern cellular, molecular, and genetic research. However, the goal is not simply to teach techniques in isolation, but also to help enrolled students learn how to develop experimental strategies that can lead to a better understanding of molecular processes. Course learning objectives include that enrolled students will be able to:

- practice fundamental aspects of experimental design, with a focus on answering questions of a molecular and genetic nature;
- gain hands-on experience with molecular research techniques as they complete several research projects;
- describe the purposes of, and theory behind, the experimental methods they use; and
- interpret and effectively communicate experimental results.

We designed the course to have experimental modules. Two modules investigate the presence and effects of insertion mutations in the model plant *Arabidopsis thaliana*. A third module uses RT-PCR to assess the effect of mutations on gene expression in the nematode *Caenorhabditis elegans*. A fourth module uses microbiological and molecular analyses to test for the presence of methicillin-resistant *Staphylococcus aureus* on the campus. The final module focuses on bioinformatics analyses, where students define a family of genes in the *C. elegans* genome and investigate evolution of the gene family.

THE APPROACH AND COURSE DEVELOPMENT SCHEDULE

Course development began 15 months before the first offering of the course with conversations within the department about topics and skills to include as well as preparation of a formal course proposal (Table 1). Discussions about how to implement the course coincided with ongoing dialog about assessment and increasing opportunities for students to get involved in research. From this intersection of ideas came a plan to embed assessment and undergraduate student research opportunities within development of the course itself. We thought that involving undergraduate students (student developers) in the process would be advantageous for multiple reasons. The student developers on the team could give feedback to the faculty about the course and help implement assessment during the first iteration of the course. Involvement would benefit the student developers by providing extended, in-depth, hands-on laboratory, and SoTL research experiences that would enrich their undergraduate education.

The faculty involved developed a basic framework for the syllabus and detailed plans for the modules during the 2015/2016 academic year. Funding was secured to support the work of team members for eight weeks during the summer of 2016. This work primarily consisted of testing and troubleshooting modules. During this time, team members worked closely to test and revise laboratory protocols associated with four of the five experimental modules developed for the course. For example, initial attempts by the student developers to amplify particular cDNAs using PCR (for the module involving the effect of mutations on gene expression in the nematode *Caenorhabditis elegans*) were unsuccessful. Therefore, the student developers, in consultation with faculty team members, checked reagents and tried modified protocols including different primer combinations. This approach resulted in a protocol that the lead faculty instructor was confident would work consistently when the course was offered. In addition to troubleshooting and revising protocols, the lab manager and student developers developed a budget for the course, a schedule for lab preparation, and calculated quantities of supplies needed for the class.

Refinement of the modules, finalization of the syllabus, and development of the assessment instruments occurred during the fall of 2016. The development of a new course provided an opportunity to develop and embed assessment in the course from the outset. Instead of designing assessment tools retroactively, we used a backwards design approach to course development and incorporated methods to measure the success of the modules at helping students achieve the learning objectives (13).

During the first course offering in spring 2017, pre- and post-surveys assessed enrolled students’ perception of their knowledge and their actual knowledge (Supporting Materials. S1. Assessment questions and scoring rubric). The knowledge questions asked the enrolled student to define and identify key concepts from the course learning objectives. All pre- and post-surveys were matched and then de-identified before analysis. Participation in the surveys did not factor into enrolled student grades. The student developers analyzed the surveys using rubrics developed by the faculty research mentor. This analysis provided the opportunity for student developers to work with data, optimize questions and further develop their skills in statistical analysis. We saw improvements in both

enrolled student confidence and knowledge at the conclusion of the lab modules (results will be reported elsewhere). These analyses informed future iterations of the course.

TEAM WORK

Course development involved multiple team members as well as support from several sources. The core team was comprised of the faculty lead instructor (D.G.), a faculty research mentor with experience in SoTL (J.L.G.), the department lab manager (C.C.-W.) and two student developers (H.A. and K.V.). In addition, both the Department of Biology and the University's Center for Excellence in Teaching and Learning (CETL) provided guidance and financial support. We clearly delineated individual responsibilities from the outset. The faculty lead instructor was responsible for developing the syllabus and lab modules for the course (done in conjunction with other molecular biology faculty), assisting in obtaining necessary reagents and equipment, revising the lab modules based on the student developers' feedback, and ensuring that assessments were given at the appropriate times during the first offering of the course. The faculty research mentor wrote a proposal to CETL to secure funding for the project, coordinated the project, and designed and analyzed the assessment tools. The lab manager recruited and directly oversaw the student developers, facilitated optimization of the lab modules, and helped to secure reagents and equipment. Both faculty members and the lab manager mentored the student developers on different aspects of the project. The student developers optimized the procedures for the lab modules, gave specific written feedback to improve the clarity of the module instructions, were involved in the analysis of the assessment materials, and presented their experience at a university-wide student research symposium. As each team member had multiple and sometimes overlapping responsibilities, effective communication was key to the project's success.

RECRUITMENT OF STUDENT RESEARCHERS

The laboratory manager identified the student developers for the project, selecting individuals with whom she had previous positive professional and academic relationships, as their instructor, mentor or employer. In addition, the two student developers were selected based on how they represented the population that would be enrolled in this course, with a focus on bringing in two student developers with different personal backgrounds, different scientific skillsets, and differing numbers of years of undergraduate experience. It is an institutional goal at our university to create an educated and informed work force but more importantly, to provide opportunities for our students to develop the skills to work with those who are different from themselves (14). While the student developers shared a history of academic achievement and a strong work ethic, their different perspectives and backgrounds proved critical in problem solving and project success.

SUPERVISION AND MENTORING OF STUDENTS

While the primary goal of the project was to develop and test a new course, we also sought to provide an enriching bench laboratory experience for the student developers involved. The laboratory manager provided direct on-site supervision and mentoring of the two student developers during the

8-week summer work period when the modules were tested. This included explaining the goals of each lab, assisting in developing schedules and goals, demonstrating procedures and equipment, addressing safety concerns, and providing reassurance. In addition, the laboratory manager facilitated communication with the research mentor and faculty lead instructor when they were not physically present.

We specifically emphasized working together as a team. Team-building opportunities helped to develop a sense of belonging. Student developers lunched together daily during the summer. There were opportunities to socialize with team members and other department faculty. Good laboratory note taking and documentation, as a shared responsibility, was emphasized. Any errors in performing the procedures were considered a group responsibility to solve. Trust amongst all team members developed as the project progressed, and the student developers understood that they each brought value to the project.

CONCLUSIONS: Benefits, challenges and looking forward

This model of course development benefited the team members involved, the enrolled students in the class, and the biology department as demonstrated by interviews with all team members. By devoting time and resources to course development and involving undergraduates, we were able to think intentionally about how to shape the laboratory modules to fit our population of students. For instance, the involvement of two student developers who were at different points in their academic careers helped us to see how the modules might be received by enrolled students with varying levels of preparedness. The approach ensured that the materials and timeline were realistic in the hands of relatively inexperienced undergraduate students. Furthermore, having two student developers working so closely with professors throughout the development process allowed us to better understand the learning capacity of the students so that what was expected of enrolled students taking the course was realistic and manageable for them. For example, the faculty lead instructor devoted more time to explanation of phylogenetic tree interpretation during the bioinformatics module based on his interactions with the student developers. We found that the process of explaining the experiments and the related background content to the two student developers essentially served as a "practice run" for this part of the faculty lead instructor's role in the course, which helped the instructor feel more comfortable during the first course offering.

We found that the success of this model depended on clearly defined responsibilities for team members, effective communication, flexibility, and willingness to adapt to changing needs. The faculty involved relied on the scientific and mentoring expertise of the lab manager to provide the day-to-day supervision of the student developers. The laboratory manager relied on the faculty lead instructor and the faculty research mentor to develop the modules, educate the student developers on the theoretical background for the experiments, and provide context as to how the modules would be used in the course. The faculty and the lab manager relied on the student developers to give accurate and informative feedback about modules. All members of the team needed to be willing to make modifications as problems arose.

Looking forward, we would make some modifications when

using this model of course development again. We had not planned to have one of our student developers also serve as an assistant for the first offering of the course but found that this turned out to be key for success. In part, this was because the student developer could empathize with enrolled students when they were struggling with technical details of the protocols. Additionally, she quickly and effectively could communicate any issues that arose during a class period with the lab manager because of her prior experience with the experiments. The faculty had ideas for additional modules, which, given time, we could have had the student developers test. While there is not time in a semester to add more modules to the five currently used, additional modules, kept “in reserve”, would make it possible to modify the course from semester to semester in response to changing student or instructor interest, scheduling alterations, or changing material/reagent availability. Thus, this model for course development could be also used when updating or modifying a currently offered course.

While we did use all modules tested by the student developers, we could envision scenarios where inclusion of certain modules in the course would need to be reconsidered. For instance, if the student developers could not get protocols to work, it is unlikely that the protocol would work during the course offering. Additionally, if the student developers struggled to understand the theory behind the experiments in a module, faculty may need to reconsider the appropriateness of the module for the course.

We used this team-based course development model in a modified format for the development of another laboratory course in the department, a middle-level genetics lab. Due to time and staffing constraints, only one student developer and one faculty instructor comprised the team. We found that this smaller team did not work as well; the process would have benefited from broader expertise and perspective provided by additional team members. On the other hand, similar to the cell/molecular biology course, the student developer assisted with the first course offering, which confirmed for us the value of this arrangement.

While this model of course development proved valuable for the faculty, the department, and the enrolled students taking the course, based on interviews conducted with all team members at the completion of the project, we believe the greatest benefits may have been for the two student developers. The student developers identified that, through the process, they learned new skills and lab techniques, had beneficial interactions with professors as mentors, improved their ability to think critically and learned how to conduct research properly in a team setting. Hands-on laboratory experience is critical for biology majors: those experiences are typically obtained through teaching labs or faculty-student collaborative research. Faculty-student research in particular can provide an extended, in-depth, intensive experience at the lab bench. However, in our department there are fewer of those opportunities available than students who desire them. This model of course development provides another way for students to participate in a high-impact experience, and we intend to continue to use it in the department. For those considering implementation of this model, we have included a guide in the supporting material, S2.

SUPPORTING MATERIALS

- S1. Team-Based Approach to Course Development-Surveys and Rubrics pre- and post-surveys for assessment
- S2. Team-Based Approach to Course Development-Guide to considering this approach

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Table 1. A time line for the team-based course development approach. Timing of these tasks will depend on your institution's procedures and deadlines but the following is the timeline that we followed.

Time Prior to 1st Offering of the Course	Tasks
12 to 15 months (fall semester)	Discuss learning objectives within department and align with course modules Identify literature and resources on the specific learning objectives Prepare formal course proposal Discuss approach to course development
9 to 12 months (spring semester)	Develop detailed plans for modules and a syllabus Recruit student developers Secure funding to support team members Prioritize modules to be tested Research extant assessment tools Draft assessment tools Define team member roles and responsibilities
3 to 6 months (summer)	Test and revise protocols Develop course budget, schedules and supply lists Test and edit assessment tools Mentor student developers
0 to 3 months (fall semester)	Refine and finalize lab modules and assessment tools Encourage student developers to reflect on their experiences Discuss team roles during course offering (e.g. student developer as course assistant, preparation of final reports to funding sources, SoTL research and assessment of course)