RESEARCH ON LEARNING

Strategies to Promote Effective Student Research Teams in Undergraduate Biology Labs

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Abstract

Biology labs often make use of student teams. However, some students resist working in teams, often based on poor experiences. Although instructors sometimes struggle with student teams, effective teams in biology labs are achievable. We increased student learning and satisfaction when working in research teams by (1) including in the syllabus a teamwork learning objective "to practice effective teamwork and team management, including modeling behaviors of inclusion and ethics, and using leadership skills to foster problem solving, team communication, conflict management, consensus building, and idea generation"; and (2) designing and implementing exercises that teach students the value of working in a team and how to be part of an effective student team (e.g., developing shared expectations, creating norms of behavior and team culture, and building awareness of the importance of team conflict and likely student responses to such conflict). We also used individual and team reflections on team functioning, following formal online team assessment. This article presents details about our curricular innovations as well as pretest and posttest data demonstrating student attitudes and beliefs regarding teamwork. We experienced improved student satisfaction and success in introductory biology lab courses, as well as reduced instructor guesswork and stress regarding student teams.

Key Words: *biology education; cooperative learning; science practices; student research teams.*

○ Introduction

In response to calls for improved science and math education (e.g., AAAS, 2011, 2015; Bradforth et al., 2015; Cooper et al., 2015), many college biology instructors implement reform-based science education in their courses. Often these changes involve replacing more traditional, lecture-based, teacher-centered modes of instruction with interactive, student-centered, and inquiry-based instruction (Seymour, 1995; National Research Council, 1996; National Science Foundation, 1996; Freeman et al., 2014). These changes may be especially important for introductory-level courses that initially expose students to college-level science topics and processes and that can sometimes serve as impenetrable "gateways" to advanced science courses and reduce student persistence in STEM fields (Gardner & Belland, 2012; Kazenpour et al., 2012).

Some instructors have reformed their introductory biology classes by implementing inquiry-based labs that emphasize science process skills, the ways scientists study the natural world, and the use of evidence-based explanations (e.g., DebBurman, 2002; Luckie et al., 2004; Spronken et al., 2011). Since much of science is conducted by teams (Wuchty et al., 2007), implementing inquiry-based labs often goes hand-in-hand with implementing collaborative and/or cooperative learning strategies. Research on cooperative learning has found favorable outcomes associated with productivity and achievement, inter-group attitudes, attitudes toward learning, and psychological health and self-esteem (e.g., Johnson et al., 1998; Springer et al., 1999; Emke et al., 2016; Hanson et al., 2016). Therefore, instructors who employ inquiry-based learning in conjunction with cooperative learning in their classes might expect positive student attitudes and high levels of learning.

In contrast to these expectations, some students resist working in teams, and instructors often struggle with how to help student teams be effective. One reason for these struggles may be the sometimes overlooked distinction between collaborative and cooperative learning. Collaborative learning is characterized as an unstructured instructional strategy whereby participants negotiate goals, define problems, develop procedures, and produce socially structured knowledge in small groups (Springer et al., 1999). In stark contrast to this instructional approach is cooperative learning, in which small groups work together in instructor-structured ways such as those described below (Johnson et al., 2006, 2014; Herrmann, 2013; McClellan, 2016).

Cooperative learning is the instructional use of small groups so that students work together to maximize their own and each other's learning (Johnson & Johnson, 1974; Smith et al., 1981; Johnson et al., 1991). Carefully structured cooperative learning involves people working in teams to accomplish a common goal under conditions that involve both positive interdependence (all members must cooperate to complete the task) and individual and group accountability

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(each member individually and all members collectively are accountable for the work of the group). This structure always includes a common goal, such as "All students achieve mastery," and can include assigning award-based motivation for achieving group goals; assigning specific, complementary, and interrelated tasks to each group member; holding each individual accountable for their learning; providing team-building activities or elaborating on the social skills needed for effective group work; and discussing ways in which each group's work could be accomplished more effectively (Smith et al., 1981; Springer et al., 1999; Hughes & Jones, 2011). When ignored, these last two features of cooperative learning may have strong negative effects on student attitudes and learning. In fact, in our experience in introductory biology, unstructured collaborative learning results in student frustration and team dysfunction. Curiously, some instructors and students do not place high importance on fostering teamwork skills. For example, a review of online introductory biology syllabi finds few classes with teamwork among the science process skills to be learned and practiced. Many students have had bad experiences working in past teams and do not recognize the need for conducting science in teams (K.S. Cheruvelil, personal observation). Lacking the will or the skill to work as part of an effective team, students (and their instructors) can struggle in team- and inquiry-based labs.

Two recent reports from the National Research Council, *Education for Work and Life: Developing Transferable Knowledge and Skills in the 21st Century* (2012) and *Enhancing the Effectiveness of Team Science* (2015), call for enhancing students' preparation for working effectively on teams. The latter concludes: "A strong body of research conducted over several decades has demonstrated that team processes (e.g., shared understanding of team goals and member roles, conflict) are related to team effectiveness" (National Research Council, 2015). Employer surveys also list teamwork skills among the top sought-after skills (Hart Research, 2015; NACE, 2015).

Our goal was to help students develop these transferable skills and to increase student learning and satisfaction when working in research teams. We added an explicit teamwork learning objective to our biology lab course, designed and implemented exercises that teach students the "whys and hows" of effective teamwork, and implemented teamwork assessments with CATME (https://www.catme.org; Ohland et al., 2012). This article shares our curricular innovations and data demonstrating student attitudes and beliefs regarding teamwork. Our teamwork materials should be applicable and modifiable for other courses that use student teams, resulting in improved student satisfaction and success, as well as reduced instructor guesswork and stress regarding student teams.

○ Methods

Study Context: Introductory Organismal Biology Course

Here, we describe a decade-long effort to improve student teamwork in an introductory biology class. In our own experiences, students complained about working in teams and teams struggled to work effectively together, which negatively affected their ability to conduct student research. Therefore, we created a teamwork lab module that includes teamwork learning goals, a robust and evidence-based approach to explain the "whys" of teamwork, and exercises to build the "hows" of effective teamwork. We also discovered Team-Maker/CATME, which is the online evidence-based system that we use to create teams and formally assess team functioning (https://www.catme.org; Loughry et al., 2007, 2014; Layton et al., 2010; Ohland et al., 2012) and developed an exercise that complements CATME to help students and teams reflect on and adjust their behaviors to increase team functioning.

The assessment of student attitudes and beliefs regarding teamwork was conducted during two semesters of the Lyman Briggs College (LBC) introductory organismal biology course (LB144; four credit hours) at Michigan State University. During fall 2015, 111 students completed the course, which included 13 weeks of lab; and during spring 2016, 88 students completed the course, which included 14 weeks of lab. Students attended two 80-minute class sessions per week and a three-hour combined recitation and lab. Although lecture content and style varied somewhat, depending on the instructor, there were common learning goals related to the major topics of ecology, evolution, and diversity of life, and the instructors used a variety of active-learning and student-centered approaches (e.g., mini-lectures interspersed with small-group exercises, individual and paired writing, personal response pad [clicker] questions, and case studies). The combined recitations/labs met in sections of 16–20 students each, staffed by two undergraduate learning assistants and either an LBC professor or a graduate teaching assistant. The lead author was the lead lab professor for both of these semesters and all lab sections were taught by equivalent teaching teams using the same instructional materials and activities. Students in the recitation/labs worked in teams of three or four students, yielding four to six research teams per lab section.

During the 2015–2016 academic year, this course consisted mainly of Michigan students, more than half of whom were female, and ~20% were from underrepresented racial/ethnic groups (Table 1). They were approximately half first-year and half second-year students. Students entered the class with a range of biology backgrounds and math preparedness and represented a variety of science majors (mainly human biology and biological science; Table 1); many aspired to careers in the allied health fields.

Teamwork Learning Goals

As we developed and implemented the teaching and learning materials to teach students how to be part of an effective team (see below), we experienced students resisting our allocation of lab time to teamwork training. Students would commonly complain that they wanted to "do biology!" This experience was in stark contrast to our perceptions of science research being conducted in teams (Wuchty et al., 2007), with science productivity and outcomes being highly reliant on team functioning (Cheruvelil et al., 2014; Read et al., 2016). In addition, some biology instructors struggle with adding teamwork-related activities to their classes because of the perception that there will necessarily be a trade-off of reduced biology content covered. To counter those perceptions, we added explicit teamwork learning goals to our lab syllabus:

Students should excel at effective teamwork and team management by

(a) modeling behaviors of inclusion and ethics, and

(b) using leadership skills to foster problem solving, such as effective communication, conflict management, consensus building, and idea generation.

Table 1. Student demographic data from fall 2015 and spring 2016. Self-identified gender and race/ethnicity data are from online surveys with 93% and 88% response rates during 2015 and 2016, respectively (11 and 8 students, respectively, chose not to answer these two questions) (Team-Maker; Layton et al., 2010). Class years and majors are from institutional data. Approximately 80% of students were Lyman Briggs (LB)-declared majors during these two respective years. Note that these data are for the entire class each year; however, students could opt out of online assessment surveys (CATME; Loughry et al., 2014), and we discarded incomplete or unmatched surveys.

	Fall 2015		Spring 2016	
	n	%	*n*	%
Gender				
Male	37	33	33	37
Female	74	67	55	63
Race				
Asian	11	10	10	11
Black	4	4	13	15
Hispanic	8	7	6	7
Native	1	1	0	0
Other	5	5	10	11
White	82	74	49	56
Class Year				
Freshman	5	4	60	60
Sophomore	106	89	33	33
Junior	6	5	6	6
Senior	2	2	1	1
Majors				
Environmental Sciences	1	1	3	3
Human Biology	18	15	5	5
LB Biological Sciences	90	76	86	85
LB Chemistry	2	2	1	1
LB History, Philosophy, and Sociology of Science	0	0	2	2
LB Physics, Chemical Physics, and Astrophysics	4	3	1	1
Mathematical and Computational Sciences	3	3	2	2

This learning goal was introduced during week 1 of lab, described in full during week 2, and then revisited periodically over the course of the semester (Figure 1).

The Whys & Hows of Effective Teamwork

We created a three-hour lab module focused on improving student teamwork, based on years of experiences teaching labs with student teams and heavily informed by the last author's workshops and by *Teamwork and Project Management* (Smith, 2014). The overarching goals of this three-hour lab module about the "whys and hows" of effective teamwork were (1) developing shared expectations, norms of behavior, and team culture; and (2) building awareness of why team conflict is important and how students are likely to respond to such conflict. The module includes pre-lab reading, lab mini-lectures, and lab exercises (Appendices 1 and 2; all appendices are available as Supplemental Material with the online version of this article). We introduced the importance of teamwork in science careers during week 1; used online software that helps instructors use self-chosen and evidence-based criteria to deliberately create student teams (Team-maker/CATME; https://www.catme.org; Layton, et al. 2010; Loughry et al., 2014) between weeks 1 and 2; placed students in their semester-long teams at the start of lab during week 2; and implemented the "whys and hows" lab module during labs in week 2 (Table 2).

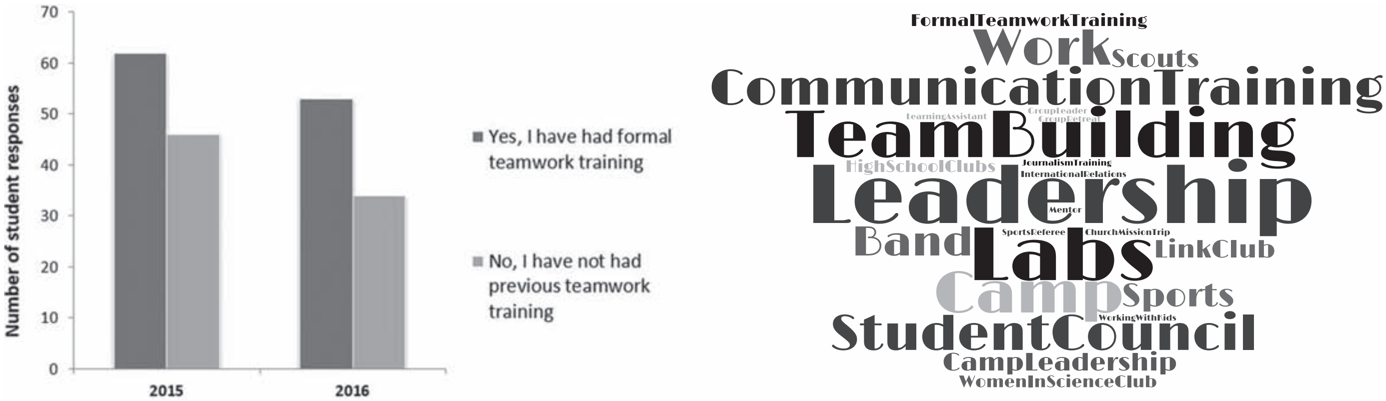

Figure 1. Students' self-reported (2015 and 2016) prior experience with formal training in teamwork skills such as leadership, team building, and communication. The prompt was "I have had previous formal training in teamwork skills such as team building, communication, or leadership training. Yes/No, and *if Yes*, what type and in what context?" (**A**) Numbers of students who believed that they had or had not experienced previous training. (**B**) A word cloud showing the self-reported ways students described prior leadership training experiences (responses from the two years pooled). Larger font size indicates a larger proportion of students providing that response.

Table 2. A semester-long schedule of teamwork-related activities. Note that the teamwork "whys and hows" can be delivered in one three-hour module or broken up into a series of shorter modules during the early weeks of the semester. See Appendix 1 for more details.

Activity	Week(s)
Attitudes pretest	1
Form teams	2
Informal teamwork assessment and team dysfunction troubleshooting	1–15
Teach "whys and hows of effective teamwork"	2
Formative biology assessment	6, 10
Formative teamwork assessment	7, 11
Attitudes posttest	15
Summative biology assessment	14, 16

The lab module in its entirety, along with the presentation, teaching notes used to teach the module, and suggestions for teaching team preparation are included in Appendices 1 and 2. We increased student interest and investment (i.e., buy-in; Cavanagh et al., 2016) using a pre-lab reading describing teamwork as essential for conducting science (Cheruvelil et al., 2014). We then worked through a series of mini-lectures, exercises, and team and lab discussions during a structured three-hour lab session. In short, we started with the teamwork learning goals, moved into a Venn diagram exercise designed to introduce the students to each other (Appendix 2), and then conducted reflections on past team-based learning experiences (Appendix 1: Exercise 1). These have often been poor experiences for students, so their independent reflections and team discussions often started with discussions of the characteristics of past ineffective teams. However, we circulated in the lab, asking each team to brainstorm ways to improve on those experiences – in essence, describing characteristics the opposite of those they were displeased with previously. The lab discussion of the characteristics that define effective teams resulted in a long list of aspirational characteristics (Appendix 2).

The next exercise prompted students to practice some of the characteristics they had just identified as effective (Appendix 1: Exercise 2). Each student individually completed the activity before doing it as a team, and almost exclusively the team outperformed individuals. Therefore, they experienced firsthand the value of teamwork. The exercise also included a reflection on team process that helps the students build awareness of how their team may operate and provides them with opportunities to practice their teamwork skills. We did a full lab debrief on this exercise to emphasize the importance of practicing teamwork skills and the value of effective teamwork.

Following these exercises, we delivered a mini-lecture about why effective teamwork is critical for educational and career success. We tried to connect with the students on multiple levels, providing them with pop-culture and medical teamwork examples, as well as sharing data on teams in science (Appendix 2). One thing we found extremely important was repeatedly validating students' bad experiences working in teams. During the presentation, we talked about the fact that teamwork is appropriate only when complex tasks are assigned that require diverse perspectives, skills, and knowledge; when grade competition is minimized; when students are trained how to work effectively in teams; and when students are provided frequent opportunities to reflect and improve on their team functioning. We described the pitfalls of educational experiences that place students in pseudo-teams or imbalanced teams that result in students achieving equal or poorer performance (learning, grades) than they would have achieved if they had worked independently (Smith, 2014). We reiterated that in our class students sincerely need their peers to be successful and that we are committed to training them how to work in teams effectively.

This mini-lecture concluded with a presentation and discussion about conflict (Appendix 2). Even though many students (as well as professors, scientists, and doctors) are uncomfortable dealing with conflict and tend to avoid it, we taught our students that conflict is essential for their success. In fact, the sequential-stage theory of team development (Tuckman et al., 1977; Tuckman & Jensen, 2010) says that teams do not work well together until after they have successfully navigated conflict. Knowing that conflict is likely – even necessary – helped students prepare for future conflict. We taught students the five main ways of dealing with conflict (smoothing, forcing, withdrawing, confronting, and compromising; Smith, 2014) and explained that everyone uses all five of these strategies depending on their comfort level, the situation, and the person(s) involved in the conflict. However, individuals have preferred ways to deal with conflict (e.g., confrontation and compromise), and being aware of our own and our teammates' preferred ways to deal with conflicts can help students negotiate conflict successfully. We built this awareness with Exercise 3 (Appendix 1), which involves each student completing a questionnaire identifying their dominant ways of dealing with conflict, reflecting on those results, and then discussing how their collective results might influence how their team manages future conflicts. We followed that exercise with a lab debrief that had each team contribute ideas for how to best manage conflict, and we provided them some of our own ideas (Appendix 2).

The last exercise in the teamwork module has each student team develop, agree upon, and sign a team contract (Appendix 1: Exercise 4). We provided them with basic ground rules related to attending labs and team meetings and being prepared, but we asked them to discuss their goals and how to meet those goals. We circulated during this exercise to push the students to be explicit and specific about concerns and strategies. For example, how will they handle a personal crisis affecting one team member's attendance or performance? What procedure might they use if a team member stops answering correspondence? Finally, we talked about the "quit or fire clause" that, in extreme circumstances, allows any team member to quit the team or an offending team member to be fired from the team (Appendix 1: Exercise 4). This clause has very rarely been used (twice in five years), but the presence of it reassures students who have been part of teams with freeloaders in the past that they have an "out." The students were required to sign the contract, and it was revisited during the team-functioning reflections later in the semester. The formal reflection includes an individual online questionnaire that assesses student team functioning and provides students with evidence-based feedback for improving their team's performance (Team-maker/CATME; https://www.catme.org; Loughry et al., 2007; Ohland et al., 2012). After receiving their individualized team report, students individually completed Exercise 5 (Appendix 1), reflecting on how their team is working together, their role in their team's functioning, and how they would like their team to improve its performance. Then, as a team, they shared their reflections and agreed on an "improvement plan" for the rest of the semester, which sometimes involved revising their team contract (Appendix 1: Exercise 4). We did this formal team-functioning assessment twice during the semester, immediately following major summative team assessments (e.g., research proposal or poster; Table 2).

Assessing Student Attitudes & Beliefs Regarding Teamwork

We developed and implemented components of this three-hour lab module during a time span of a few years and observed steady improvement in team functioning and student attitudes. However, not until the 2014–2015 academic year did we implement a study to assess student attitudes and beliefs about teamwork. Pretests and posttests (provided in Appendix 3; MSU IRB app. no. i048943) were administered during the first and last weeks of lab and included six or seven five-level Likert-scale questions and one free-response question, respectively. The questions were designed to better understand how students felt about formal teamwork training, the benefits and challenges of working in student teams, and their beliefs about the effect of teamwork training on their teamwork skills.

Likert-scale questions were tested for internal reliability using Cronbach's alpha. Analysis of variance was used to test for differences in average responses for each question on the pretest and posttest and between years. Change in attitudes and beliefs was calculated using learning gains, whereby we subtracted the pretest score from the posttest score. Differences between pretest and posttest responses and in learning gains were compared using a series of paired *t*-tests. We tested whether students felt that learning/practicing teamwork skills and reflecting/assessing teamwork was valuable using a binomial test.

For the free-response questions, students were not limited or constrained in their responses and could identify as many or as few ways that working in a team enhanced or hindered their scientific learning. We employed a coding method to identify themes in their responses. The coder (second author) made a master list of recurring themes for both "enhancement" and "impediment," combined themes that overlapped in intellectual substance/content, and then assigned theme response values.

○ Results

Introducing teamwork learning goals, using mini-lectures and activities about the "whys and hows" of effective teamwork, and formally assessing teamwork positively affected three areas of the course: (1) student attitudes and beliefs, (2) student and team performance, and (3) instructor satisfaction. There has been an increase in student buy-in for working in teams and learning and practicing teamwork skills, as well as in their recognition of teamwork being a necessary and important part of doing biology. For example, these quotes from year-end course evaluations describe some examples of students' attitudes and beliefs regarding teamwork:

- "I learned how better to work in a group. I especially learned how to cope with difficult personalities while maintaining my cool head, and I learned how to interact and get along with people who are extraordinarily different from me."
- "[Being in a] group setting was helpful in learning better communication practices both in the small groups and in a larger setting."
- "Being placed in a good team, I was able to practice teamwork and working at a higher, more cohesive level."
- "What I enjoyed most about our group's dynamics is that we were able to assign tasks and achieve the goal faster."

The following quotes also speak to the way that the teamwork exercises may have affected student performance:

- "When it comes to teamwork I think I used leadership skills well to foster problem solving as well as modeling behaviors of ethics. I saw improvement in [my] reading and writing skills as well as speaking in small group settings."
- "It really helped how we did group work activities that took us step by step on the scientific processes. I am so much more informed on how to understand and interpret different scientific data. Teamwork really helped with brainstorming ideas for research questions and hypotheses."

More effective teamwork also resulted in fewer dysfunctional teams, which meant that instructors experienced more enthusiastic students and fewer uncomfortable team-functioning interventions. Finally, contrary to some instructors' concern that biology content will be sacrificed in order to teach students how to be part of effective research teams, we found, albeit qualitatively, an increase in the quality of the team research produced. These teaching materials and tools were extremely useful for implementing student teamwork training, assessment, and reflection in a consistent way across semesters.

Assessing Student Attitudes & Beliefs Regarding Teamwork

Forty-three percent of students reported no prior teamwork training on 2015–2016 pretests (Figure 1A). Those who did have prior training reported that it came mainly from jobs, labs, or sports team training and that it focused on team building, leadership, or communication (Figure 1B).

We found internal reliability among the five questions related to teamwork, the need for teamwork training and practice, and its value for a future career in science (Cronbach's alpha values: 0.67–0.77; Appendix 4). Interestingly, we found that the majority of students started the semester with relatively positive attitudes related to teamwork, the need for teamwork training and practice, and its value for a future career in science (e.g., average student responses were somewhat to very positive; Appendix 4). We also found some small but significant improvements in teamwork attitudes between the beginning and end of each semester (Figure 2). Specifically, students improved upon their attitude that working in teams of three to five is an effective method of learning; work resulting from a team is better than that of one individual; and work resulting from teams made up of different perspectives, skills, and knowledge is better than that of teams of students with similar traits (Figure 2; Appendix 3: questions 1–3).

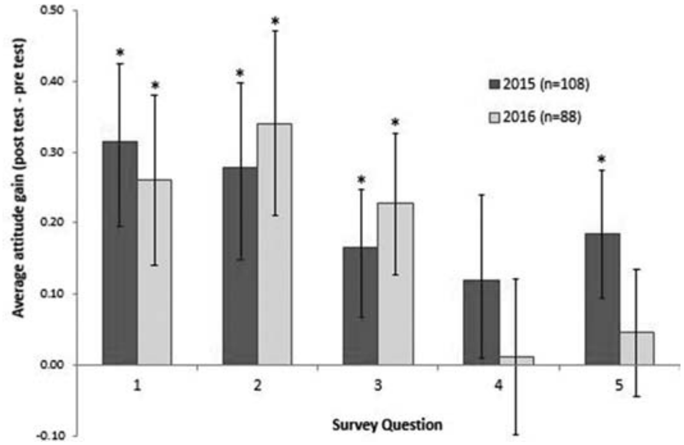

Figure 2. Learning gains (posttest score minus pretest score) representing student changes in attitudes toward teamwork from the multiple-choice survey questions administered during 2015 and 2016. Height of bars represents average difference between the posttest and pretest responses (± SE), with a positive result (higher bar) indicating that the students reported increased value of teamwork on the posttest compared to the pretest. Asterisk indicates significant differences between the pretest and posttest responses using a paired *t*-test. There were no significant differences between 2015 and 2016 responses (one-tailed *t*-test for unequal variances, *t*-stat range: −0.47 to 1.14, $P > 0.12$). See Appendix 3 for questions and Appendix 4 for the complete response scale, which ranged from 1 = Totally Disagree to 5 = Totally Agree.

When asked to describe "in what ways teamwork might enhance or impede your scientific learning," students reported that different perspectives/tools and the ability to pool knowledge (i.e., shared knowledge) were positive aspects of teamwork, whereas an uneven distribution of work and the potential for conflict were negative aspects (Table 3). There was no change in the number of "enhance" or "impede" responses between the pretests and posttests (t = −0.01 and −0.02, P = 0.46 and 0.4; one-tailed *t*-test with unequal variances). However, there were four times as many "enhancing" responses as "impeding" responses provided by students (t = 2.2 and 1.72, P = 0.02 and 0.05), which was consistent from pretests to posttests. For example, more students reported on the posttest that scientific learning was enhanced by the ability to brainstorm ideas, solve problems, and find solutions; to utilize other team members' skills and strengths; and to distribute the work and study load and make tasks more efficient to complete (Table 3). The largest change in "impeding" responses between the pretests and posttests was that 10 fewer students reported an uneven distribution of work as an impediment to scientific learning. Overall, these students came into the class with positive attitudes regarding teamwork, and these positive attitudes remained or increased after a semester of working in research teams of three to five students.

Students were generally positive about the effect of our teamwork module on the posttests. For example, 79% of students felt that the skills taught increased their team's performance (binomial $P < 0.005$), and 61% of students felt that the individual team assessments and reflections increased their team's performance

Table 3. Responses of students to the prompt "In 2–4 sentences tell me in what ways you think working in team of 3–5 students might enhance (A) or impede (B) your scientific learning." Responses from 2015 and 2016 are pooled.

(A) Enhance			(B) Impede		
Response	**Pretest (*n*)**	**Posttest (*n*)**	**Response**	**Pretest (*n*)**	**Posttest (*n*)**
Builds/strengthen ideas	18	25	If distributing work, you miss out on learning	0	6
Shared learning	77	57	Not everyone does their share/ uneven distribution of work	44	34
Idea/task collaboration	21	22	Conflicting schedules	1	7
Different perspectives/ideas	107	102	Conflicting personalities	5	5
Brainstorm ideas/problems/solutions	12	23	Conflict and difference in opinion	10	16
Increase motivation	5	1	Easier to become distracted	7	4
Prevent learning plateau	3	1	Takes time to teach others	4	8
Task management/multitasking	6	7	Some people noncooperative	8	9
Play on skills/strengths	13	31	Need to trust others to do their share	2	1
Increase mutual respect	1	1	Difficult if you're a self-studier	5	3
More fun in a group	2	7	Some members' goals don't align	6	3
More eyes to review, edit, and get the correct answer	23	29	Can stifle creativity	1	0
Remove bias by working together	9	4	Bad experiences influence future biases	4	1
Develop teamwork and leadership skills	4	6	Ideas get overruled	0	5
Develop communication and social skills	13	16	Too many cooks spoil the soup	1	0
Distribute work and study load	31	43			
Practice working in real science	8	16			
Increase creativity and innovation	4	0			
Learn responsibility and accountability	3	7			
N	**360**	**404**	***N***	**97**	**96**

(binomial $P < 0.005$; Figure 3). Therefore, these students recognized the value of learning and practicing teamwork skills and formally assessing and reflecting upon team functioning.

○ Discussion

We have described the ways in which we supported student research teams in introductory organismal biology labs. As we incrementally moved our labs to be inquiry-based over the course of a decade, we added a learning goal about teamwork, implemented a three-hour module that teaches the "whys and hows" of effective teamwork, and formally assessed teamwork. Anecdotally, we experienced positive effects on student and team performance and instructor satisfaction. During 2015–2016, when we measured student attitudes and beliefs, we found that students started and stayed positive about the value of teamwork for learning science, the value of learning and practicing teamwork skills, and the value of formally assessing and reflecting upon team functioning. In fact, after working together in a team for a semester, there were some modest increases in student attitudes/beliefs regarding teamwork. This is in contrast to what one might expect in a typical team-based class that includes no teamwork training and in which student attitudes/beliefs may decline by the end of the semester. We attribute students' positive perceptions to the fact that we have shared the teamwork module with other instructors in the college, who adapted it for their classes. In fact, about half of the students in the assessed class (2015–2016) were in their second year and had experienced first-year chemistry labs informed by some of our teamwork interventions. Therefore, the generally positive attitude regarding teams that we documented may be evidence that the student culture within our college has shifted to one that embraces and values teamwork.

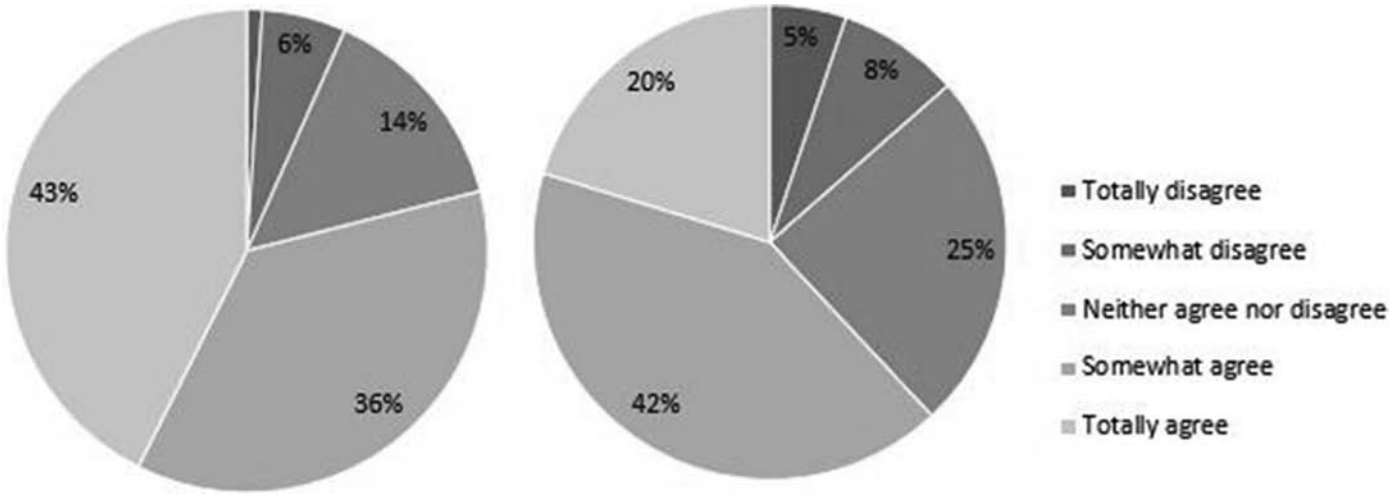

Figure 3. Posttest student responses about the value of learning/practicing teamwork skills and teamwork assessment/reflection. The two prompts were (left graph) "I believe that the teamwork skills I learned during the early part of the semester improved my team's performance" and (right graph) "I believe that the teamwork assessment survey(s), my individual reflection about the survey results, and my team's reflection on the survey results improved my team's performance" (questions 7 and 8 in Appendix 3). Responses were pooled across semesters (no significant difference between 2015 and 2016; χ^2 = 5.28 and 4.69, P = 0.26 and 0.32, for teamwork skills and assessment, respectively).

It is important to note that our module focuses more on the leadership-skills part of the teamwork learning goal and less on inclusive and ethical behaviors. However, the module includes reminders that "individual work should be done on one's own and that by adding your name to a team assignment, you are indicating that you have contributed equally to the work." As noted above, we also have a "quit or fire clause" in the team contract and reflect on team functioning multiple times during the semester. Finally, we include a section on our syllabus about characteristics of an inclusive learning environment, and model and expect inclusive behavior of our students (Appendix 1). Still, the explicit training of behaviors related to inclusion and ethics is increasingly important (Puritty et al., 2017). Future work to design and assess activities to build cultural literacy and research ethics for individuals and teams will provide further opportunities for students to learn and practice transferable skills that are highly sought after by employers, regardless of sector (Hart Research Associates, 2015; McClellan, 2016; NACE, 2017).

Teaching students the "whys and hows" of effective teamwork should be broadly applicable to other classes, regardless of university level or subject. When adapting this module for other situations, it will be helpful to consider three things: which assignments are team-based, how well instructors are trained in teamwork, and how team assignments and functioning will be assessed. First, although working in teams is sometimes necessary when resources are limited (e.g., fewer microscopes than students), team assignments have to be difficult and need people with diverse backgrounds and skills. In fact, if teamwork is used for assignments that are easily done individually, students will be frustrated by the need to coordinate with and rely on others. Second, it is likely that many instructors will have never received teamwork training. Understanding the biases instructors bring to the classroom about teamwork, and building their own teamwork skills, will improve class outcomes. For example, in our experience it was essential for instructors to understand that team conflict is essential and constructive for effective teams (Tuckman & Jensen, 1977, 2010; Johnson et al., 2000; Lau et al., 2014; Frame et al., 2015; Smith et al., 2015), to be aware of their own dominant modes of dealing with conflict, and to be comfortable enough with conflict to let it unfold in their classrooms. Third, we found it important to provide many opportunities for both individual and group assessment of team functioning. Over the years, we realized that incentivizing these opportunities was essential, so we made reflections worth points. Our use of evidence-based online team surveys (Team-Maker and CATME; Layton et al., 2010; Loughry et al., 2014), paired with individual homework and in-class team reflective assignments, has improved instructor understanding of how the teams are functioning and student understanding of ways to change behavior to positively affect team functioning and learning.

In the past, we had found high levels of student frustration and team dysfunction when we employed unstructured collaborative learning. Therefore, we shifted our team-based instructional model from collaborative learning to cooperative learning in which small groups work together in instructor-structured ways (Hughes & Jones, 2011; Herrmann, 2013). In sharing our experiences of teaching students the "whys and hows" of effective teamwork in introductory biology lab, it is our hope that other instructors will use and adapt the module for their classes. The effects of such interventions may be far-reaching. For example, we know that competitive learning environments tend to drive away women and other underrepresented groups from STEM fields (e.g., Tobias, 1990; Seymour, 2001; Espinosa, 2011; Puritty et al., 2017). The fact that our classes were made up of mainly self-identified white and female students suggests that a larger positive effect of these interventions may be seen in more diverse educational settings with more heterogeneous teams. Therefore, helping students work effectively in teams has potential for increasing diversity in STEM, especially when implemented in introductory or "gateway" courses.

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○ Author Contributions

K.S.C. designed the project, exercises, assessments, rubrics, and analytical framework. A.D.D. scored the assessments (K.S.C. conducted calibration exercises), summarized data, and conducted data analysis. Both K.S.C. and A.D.D. taught sections of the courses in which the interventions were implemented and assessed, conducted literature review, interpreted results, and wrote and revised portions of the manuscript. The interventions were inspired by two workshops by K.A.S., who also provided background information, facilitated faculty professional development on cooperative learning, and wrote and revised portions of the manuscript.

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ABT AUTHORS & PHOTOGRAPHERS

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We encourage our readers, biologists with teaching interests, and biology educators in general, to write for *The American Biology Teacher.* This peer-reviewed journal includes articles for teachers at every level, with a special focus on high school and post-secondary biology instruction.

Revised August 2018

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The general categories of articles are:

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a. Research on teaching alternatives, including evaluation of a new method, cooperative learning, concept maps, learning contracts, investigative experiences, educational technology, simulations and games, and biology and life science education standards

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