A Foundation for STEM Success: A Simple and Successful Microscope Intervention in a General Biology Course at an Urban Community College

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A variety of factors contribute to attrition in science, technology, engineering, and mathematics (STEM) education at the community college level including underpreparedness, lack of confidence, and broader socioeconomic issues. This work describes our efforts to improve student learning and overall success in a community college General Biology I lab course through the implementation of microscope clinics specifically designed to improve student microscope skills. We measured the effectiveness of our clinics using pre- and postclinic surveys as well as student performance on a microscope practicum. The majority of targeted students responded positively to the clinics and subsequently performed well on a hands-on microscope practicum. We feel that efforts such as ours can help students master a specific task of relevance to their further studies while simultaneously increasing confidence in their overall STEM "identity," leading to improved performance across their educational landscape.

Community colleges play a vital role in maintaining access to higher education for broad swaths of the population. Community college students come from diverse backgrounds and face unique challenges (e.g., full-time employment, child-care needs, low-income households, and complex immigration status; Broton & Goldrick-Rab, 2016; Terriquez, 2015). These individual challenges form the basis of programmatic challenges, such as maintenance of full-time status and retention (Watkins & Mazur, 2013). This is particularly true in STEM education, where high attrition rates are consistently observed across the United States (Hagedorn & DuBray, 2010). A variety of factors have been identified that contribute to this lack of student success, including weak basics skills and broader socioeconomic factors (Wladis, Conway, & Hachey, 2015). STEM students at community colleges typically confront these challenges for the first time in a foundational major's course, where the pace and rigor of the material overwhelm many students (Lloyd & Eckhardt, 2010). At our institution, the first science at the major's level course taken by the majority of natural science majors is General Biology I (SCB 201).

General Biology I is the first half of a two-semester course sequence required for biology and environmental science majors, as well as for a variety of allied health programs. The curriculum follows the standard trajectory, where General Biology I focuses on such topics as basic chemistry, cell structure, and genetics, and General Biology II covers physiology, ecology, and evolution. Although there is considerable overlap, we can summarize the course differences by stating that General Biology I focuses on the molecular and microscopic, whereas General Biology II covers the organismal and macroscopic. Typically, at both 2- and 4-year colleges, General Biology I requires no science prerequisites and includes a laboratory component where students are required to perform a variety of basic laboratory skills.

Mastery of basic laboratory skills, paramount among them microscopy, is not only essential for success in General Biology I, but also is a foundational skill set on which students build in subsequent courses. In fact, for biology, environmental science, and many allied health majors at our institution, microscopy is embedded in each of their subsequent required science courses. Yet, anecdotal conversations with instructors teaching these higher level courses have consistently suggested a gross lack of competence in basic microscope techniques. Accordingly, students who do not master these skills continue on to their next courses with a serious impediment. Thus, we find that there is potential for the lack of microscopy skills to be a contributing factor in preventing students from successfully completing their course of study (Domin, 1999).

Microscope techniques and concepts are primarily taught in the laboratory section of general biology courses including those at our institution. On the first day of class, students are introduced to the microscope through a lecture describing how the compound light microscope works, the functions of its various parts, and proper microscope technique. Students are then given the opportunity to work with their own microscope, examining prepared slides before progressing to the preparation and observation of their own using plant and animal tissue. Students are subsequently quizzed on their microscope knowledge and are expected to use the instrument several more times over the course of the semester. However, as evidenced by input from instructors of higher level courses, this approach may not be sufficient for inculcating microscope skills. As the semester progresses, assessment of these skills abates, and students tend to focus less on maintaining or even increasing their microscopy skill set. Additionally, the impact of such deficiencies on student success in future science courses may be obscured by the grading structure for many courses, in which microscope skills represent a small fraction of the overall course grade. In light of these issues, this article describes efforts to improve student outcomes in a general biology course for majors at a large, urban community college serving one of the nation's most diverse student bodies. The initiative, for which a primary objective was improving microscopy skills, included the creation and hosting of microscope skills workshops or "clinics" held within 3 weeks of a microscope laboratory practicum administered at the end of the semester.

A variety of college-level microscope training approaches have been described, including approaches incorporating graduate student tutors as part of a "manipulative skills" development effort in a large physiology course (Moni, Hryciw, Poronnik, Lluka, & Moni, 2007), the use of peer-generated instructional videos (Tulloch & Spiller, 2015), and previous work done at our institution describing the implementation of formative assessments (Keller, 2017). Despite these examples, much of the previous work in this arena has focused on the use of virtual microscopy in online

TABLE 1

Microscope clinic pre-and postsurvey statements, questions, and reflection prompts. Possible responses to statements 1–5 were *strongly disagree, disagree, agree,* and *strongly agree*. Possible responses to question 6 were "yes," "no," and "not sure."

Preclinic
Statements
1. I am confident that I can find a cell and bring it into focus under the microscope.
2. I am confident preparing a slide using my cheek cells.
3. I am confident and well prepared for using a microscope in lab and the final practical exam.
Postclinic
Statements/questions
1. I am confident that I can find a cell and bring it into focus under the microscope.
2. I am confident preparing a slide using my cheek cells.
3. I am confident and well prepared for using a microscope in lab and the final practical exam.
4. The workshop was informative and helpful for my learning.
5. The faculty at the workshop was helpful.
6. Based on your experience at the workshop, how well were you able to perform the exercise after the workshop?
7. Would you recommend this workshop to another SCB 201 student to prepare for their microscope practical exam?
Reflection prompts
8. Before coming to the workshop, what specific aspects of the exercise were you unable to complete or did you have difficulty with?
9. After the workshop, do you still have any questions about the exercise? What are these questions?
10. Do you have any suggestions for future similar microscope workshops? What should be added or taken out of the workshop?

science courses (Whalley, Kelley, & Tindle, 2011) or microscope training in higher level undergraduate or medical courses. Only a small number of studies involving microscope interventions have been published that specifically target first-year biology students attending community college. The microscope clinics discussed here add to that relatively small body of literature. Our microscope clinics provide an opportunity for students to reinforce basic microscope concepts, as well as to practice its usage under the guidance of faculty. We have run our microscope clinics for two semesters and report generally positive outcomes.

Materials and methods

Microscope clinics were held in the spring and fall semesters of 2017. One laboratory section of General Biology I, enrolled with 24 students, was targeted in the spring 2017 semester, while three laboratory sections were targeted in the fall semester. As the clinics were held after the withdrawal deadline, only those students still enrolled until the end of the course were able to participate, leaving a final pool of 72 eligible students (spring = 17, fall = 55). Clinics were held outside of normal class time and were not mandatory, but attendance was strongly encouraged by the General Biology I professors. The clinics were offered at two times each semester to allow for wider participation, and they were hosted by General Biology I faculty not teaching the targeted sections. Each clinic lasted 3 hours. Both clinics were hosted by the same two faculty. Students were encouraged to attend the beginning of each session but were allowed to attend the clinic at any time during the 3-hour window.

Microscope clinic content consisted of a refresher lecture on the compound light microscope and its parts, a refresher on proper technique, a discussion of common sources of error or mistakes that students encounter when using the microscope and how to mitigate them, followed by guided student practice. Following an initial reminder of basic microscope handling rules, participants were given their own microscope for the duration of the clinic. The hands-on aspect of the clinic required students to make a slide of their own cheek cells using proper technique and show it to the faculty facilitator. The same exercise formed the basis of the microscope practical quiz administered in class at the end of the semester.

We assessed clinic effectiveness through the administration of a short survey before and after the clinic, as well as a graded microscope practicum administered as part of the final lab quiz. Surveys consisted of a three-question preclinic survey, a seven-question postclinic survey, and three questions asking participants to reflect on their experience (Table 1). Statements on the pre-and postclinic survey asked respondents to *strongly agree* (SA), *agree* (AG), *disagree* (DA), or *strongly disagree* (SD), while reflection prompts were open-ended. Preclinic questions were repeated on the postclinic questionnaire, allowing pre-and postworkshop comparisons of student attitudes.

We analyzed our data in three ways using R statistical software, a language and environment for

TABLE 2

The distribution of grades on the practicum, the number of students who participated in the practicum, and the number of students who participated in the microscope clinic. In each grading category, the percentages of grades on the practicum were compared with their final percentage grade in the class using a paired *t* test. Students who received an "A" on the practicum made up the largest percentage of students who had also attended the clinic (83.7%), and these students were also the only group that earned grades significantly higher than their final percentage grade in the course.

Practicum grade	# Students at exam	# Students at clinic	Mean Δ (practicum—final grade)	*SE*	Range (min, max)	*t* statistic	*p* value
A	37	31	+17.3%	2.21	−0.8, +65%	7.803_{36}	<.001
B	6	5	+1.9%	7.65	−15.3, +32.9%	0.306_{5}	.77
C	none	—	—	—	—	—	—
D	2	1	+16.4%	1.73	−14.7, +18.1%	11_{1}	.06
F	none	—	—	—	—	—	—

statistical computing and graphics (R Foundation for Statistical Computing, Vienna, Austria; https://www.R-project.org/). For statements 1–3, which were given on both the pre- and postclinic surveys, we numerically coded the responses (SA = 4, AG = 3, DA = 2, SD = 1) and applied analysis of variance (ANOVA) with two factors (clinic and semester) as well as a term addressing possible interactions between clinic and semester. A significant interaction effect would indicate that the students' responses were affected by the semester in which the clinic was delivered in a complex, nonlinear manner.

To analyze postclinic statements 4 and 5 and questions 6 and 7, we applied a chi-square goodness-of-fit test that compared the frequency of our responses with a null category frequency that assumed an equal distribution of responses among all response categories. For question 6, which had six response categories, we used a null category frequency of 0.1670, whereas for statements 4 and 5 and question 7, we used a null category frequency of 0.125. We pooled the data for these questions as preliminary analyses showed no significant difference between semesters.

To analyze the grades, we also applied two analyses. First, we compared the practicum grades for deviance from an expected normal distribution using a chi-square goodness-of-fit test with a null normal distribution of grades centered at 75% (frequencies: A = 0.023, B = 0.136, C = 0.682, D = 0.136, F = 0.023). Second, we compared the students' percentage distribution in each grade category (F–A) to the distribution of their final grades using a paired *t*-test (Table 2).

TABLE 3

Rubric sent to students and posted on Blackboard; for speed in grading, the rubric was broken into increments of 10% beginning at 40%.

Format	
The microscope practical will start a half hour after the written exam ends. There will be three rounds, each with up to eight students. Each student will have 15 minutes during the round to create a cheek cell slide, stain it, and focus it properly at 40X. At the end of the round all students will be asked to leave, and the instructor will grade each attempt using the rubric below.	
Grading rubric	
100% 90%	An epithelial cell can be located within the field of view with a total magnification of 400X
80% 70%	An epithelial cell can be located within the field of view with a total magnification of 100X
60% 50%	An epithelial cell can be located within the field of view with a total magnification of 50X
40%	Slide is situated correctly on stage Cover slip placed correctly on slide Cheek cells are properly stained Unstained cheek cells are swabbed and on slide

TABLE 4

The mean and standard error for statements 1–3, which were numerically coded 1–4 depending on how strongly students agreed with the statement. Possible responses were *strongly agree* (SA = 4), *agree* (AG = 3), *disagree* (DA = 2), *strongly disagree* (SD = 1). These statements were further analyzed using analysis of variance (see Table 5).

Semester	*n*	Statement	Time of survey	Mean	*SE*
Spring	15	1	pre	2.93	0.26
			post	3.60	0.13
		2	pre	3.26	0.12
			post	3.73	0.12
		3	pre	2.87	0.19
			post	3.60	0.13
Fall	41	1	pre	2.92	0.09
			post	3.58	0.08
		2	pre	2.90	0.09
			post	3.56	0.08
		3	pre	2.71	0.11
			post	3.56	0.08

The responses to the three reflection prompts were analyzed and coded for themes. The percentage of responses that correspond with each theme was then compared with a null frequency distribution by assigning each category as equally likely, including no response. Reflection prompt 1, with eight categories, was assigned 0.125; reflection prompts 2 and 3, each with six categories, were assigned 0.1667.

The microscope practical exam was given during finals week as part of a final lab quiz. Preparing and viewing human cheek cells is a common exercise in General Biology courses and is used to illustrate the appearance of animal cells while demonstrating proper microscopy technique. The microscope practical exercise was graded based on appropriate technique and a correctly identified and verified cells observed at 400X total magnification. The rubric and instructions used are presented in Table 3.

TABLE 5

The results of statistical analyses of survey statements and questions (*n* = 56). Statements 1–3 were on both the pre- and postclinic surveys and were analyzed using analysis of variance with an interaction effect between the clinic and the semester. Statements 4 and 5 were only on the postclinic survey and were analyzed using a chi-square goodness-of-fit test. Bolding indicates significance in the model. See Table 3 for more information on statements and Table 5 for mean and standard error for statements 1–3.

Statement/question	Factor	*F* statistic	*p* value
1. I am confident that I can find a cell and bring it into focus under the microscope.	clinic	**$26.97_{1, 108}$**	**<.001**
	semester	$0.16_{1, 108}$	.692
	interaction	$0.12_{1, 108}$	.734
2. I am confident preparing a slide using my cheek cells.	**clinic**	**$25.92_{1, 108}$**	**<.001**
	semester	**$5.28_{1, 108}$**	**.02**
	interaction	$2.55_{1, 108}$	.11
3. I am confident and well prepared for using a microscope in lab and the final practical exam.	**clinic**	**$45.13_{1, 108}$**	**<.001**
	semester	$3.12_{1, 108}$	.08
	interaction	$2.68_{1, 108}$	.10
		χ^2 statistic	***p* value**
4. The workshop was informative and helpful for my learning.		107.57_{3}	<.001
5. The faculty at the workshop was helpful.		102.29_{3}	<.001
6. Based on your experience at the workshop, how well were you able to perform the exercise after the workshop?		52.21_{5}	<.001
7. Would you recommend this workshop to another SCB201 student to prepare for their microscope practical exam?		106.11_{3}	<.001

Results

The clinic was attended by a total of 56 students, 11 of which were from other General Biology I sections that had heard of it through word of mouth. Out of the 45 students who received a final grade in a course section targeted by the interventions, 37 (82.2%) attended the clinic (Table 2). The grades on the microscope practicum were significantly higher than the null distribution (χ^2 = 2363.6, *df* = 4, $p < .001$; Table 4), but when we compared the percentage grades students earned on the practicum with their final percentage grade in the course, only those who had received As had a practicum grade that was significantly different from their overall grade ($t = 7.803_{36}$, $p = < .0001$; Table 2). The A grading category was also the only one in which more than 50% of the students had attended the clinic (Table 2).

Survey results indicate significantly improved student confidence in their abilities to use the microscope successfully and do well on the practical exam when comparing responses to pre- and postworkshop survey items (Table 5; Figure 1). Statements 1–3 appeared on both the pre- and postsurveys, and the clinic had a significant effect on all three (Table 5, Figure 1). The percentage of students strongly agreeing with statement 1, "I am confident that I can find a cell and bring it to focus under the microscope," significantly increased from 40% to 60%

($F = 26.97_{1, 108}$, $p < .001$). The percentage of students strongly agreeing with statement 2, "I am confident preparing a slide using my cheek cells," significantly increased from 27% to 73% ($F = 25.92_{1, 108}$, $p < .001$); there was also a significant effect of semester, with both pre- and postsurvey responses lower in fall than spring ($F = 5.28_{1, 108}$, $p = .02$). The percentage of students strongly agreeing with statement 3, "I am confident and well prepared for using a microscope in lab and the final practical exam," significantly increased from 20% to 60% ($F = 45.13_{1, 108}$, $p < .001$).

Statements 4 and 5 and questions 6 and 7 only appeared on the postworkshop questionnaire (Table 1). Responses to these four items were generally favorable and significantly different from the null distribution (Table 5, Figure 2). Eighty-two percent of participants strongly agreed with the statement "The workshop was informative and helpful for my learning" ($\chi^2 = 107.57_3$, $p < .001$; S4 in Figure 2); 81% of participants strongly agreed with the statement "The faculty at the workshop were helpful" ($\chi^2 = 102.29_3$, $p < .001$; S5 in Figure 2). After the workshop, most students rated their ability to perform the procedure as "excellent" (36%) or "very well" (29%; $\chi^2 = 52.21_5$, $p < .001$; Q6 in Figure 2). All but one student (97%) expressed that they would recommend the workshop to other SCB 201 students ($\chi^2 = 155.42_3$, $p < .001$; Q7 in Figure 2).

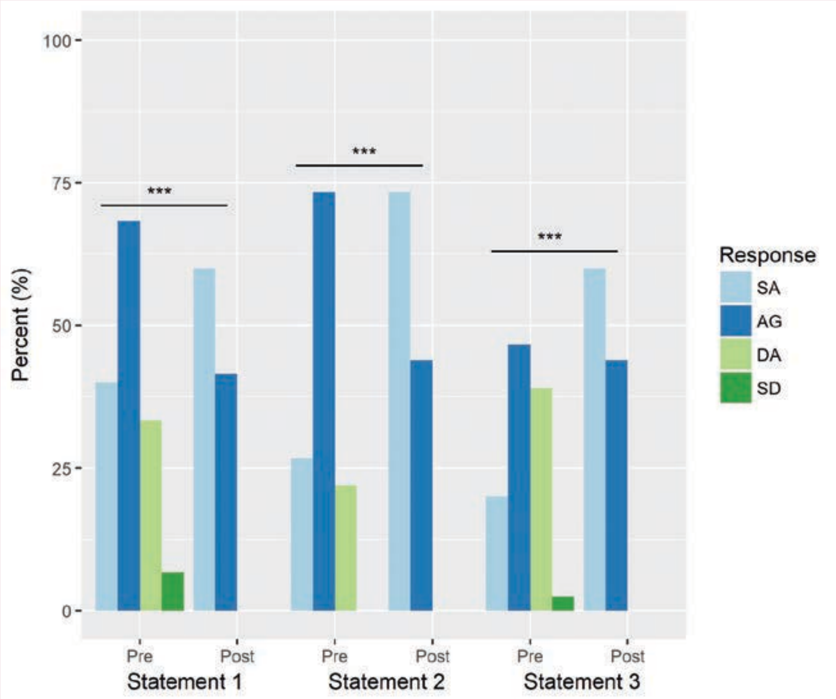
The reflection prompts were open-ended, requiring a written response from students. To facilitate analysis, answers were analyzed and coded for the themes shown in Figure 3. Students who responded to reflection prompt 1 identified locating cells, focusing, and preparing the slide as the top three areas of difficulty. The majority of participants (75%) identified an area of difficulty with using the microscope prior to the workshop. After the workshop, 62% of participants had no further concerns about using the microscope, whereas 13% wanted more practice time. Reflection prompt 3 asked students to make suggestions for improving further microscope workshops; 58% of participants responded with no suggestions or with positive feedback. Student suggestions for improving the workshops included expanding the workshop to other topics and repeating the workshop. The extra practice provided by a 3-hour microscope workshop was effective in boosting student confidence in their microscope skills while decreasing the portion of students who identify as having trouble with using the microscope.

Discussion

Our results suggest that microscope clinics, such as the one we designed and offered improve student outcomes in terms of microscope practicum grades, confidence, and attitudes regarding microscope usage.

FIGURE 1

Responses to survey statements 1–3, which were repeated on both the pre- and postsurveys and asked students about their confidence in performing certain tasks. Possible responses were *strongly agree* (SA), *agree* (AG), *disagree* (DA), and *strongly disagree* (SD). Asterisks indicate significant difference between pre- and postsurvey responses. A significantly higher number of students strongly agreed with the statements on the postsurvey. See Table 1 for information on the statements and Table 5 for the statistical model.

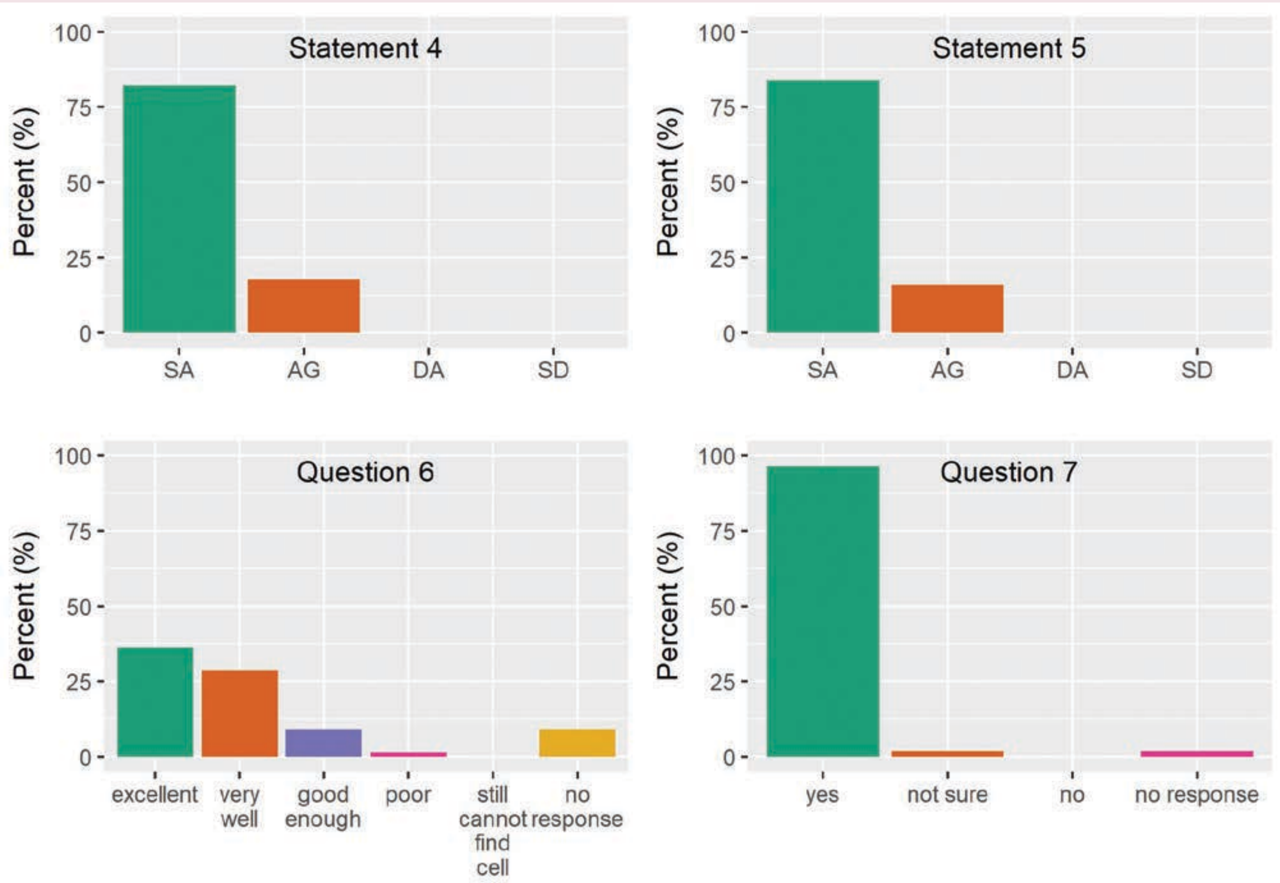


Student attitudes toward the workshop and its impact on their learning were consistently positive, with the majority of students expressing satisfaction with the workshop and increased confidence in their microscope abilities. The vast majority of General Biology I lab students who had attended the clinic received full credit on their microscope practical exam administered 1–2 weeks following the workshop.

Although mastering microscope skills represents one of many challenges facing community college General Biology I students, we feel that helping students develop skills and, perhaps more important, confidence in this one aspect of their studies may improve their educational progress in general. The percentage of the overall class grade directly based on hands-on microscope skills is quite small, and the fact that nearly all students were able to do well on the practical exam even while earning a poor grade in the class precludes quantitative statements linking the impact of our microscope clinics with student overall course grades. However, we feel that the evidence presented here supports the idea that workshops such as ours are beneficial for students and worthy of continued implementation. Although the impact of our clinics

FIGURE 2

Responses to statements 4 and 5 and questions 6 and 7. These items appeared only on the postclinic survey and asked the students to rate the helpfulness of the workshop (S4 and S5), their own performance (Q6), and their likelihood of recommending this clinic to another student (Q7). See Table 1 for more information on the items. The distribution of responses for each item was significantly different from one in which responses were equally distributed across categories. See Table 5 for chi-square statistics.

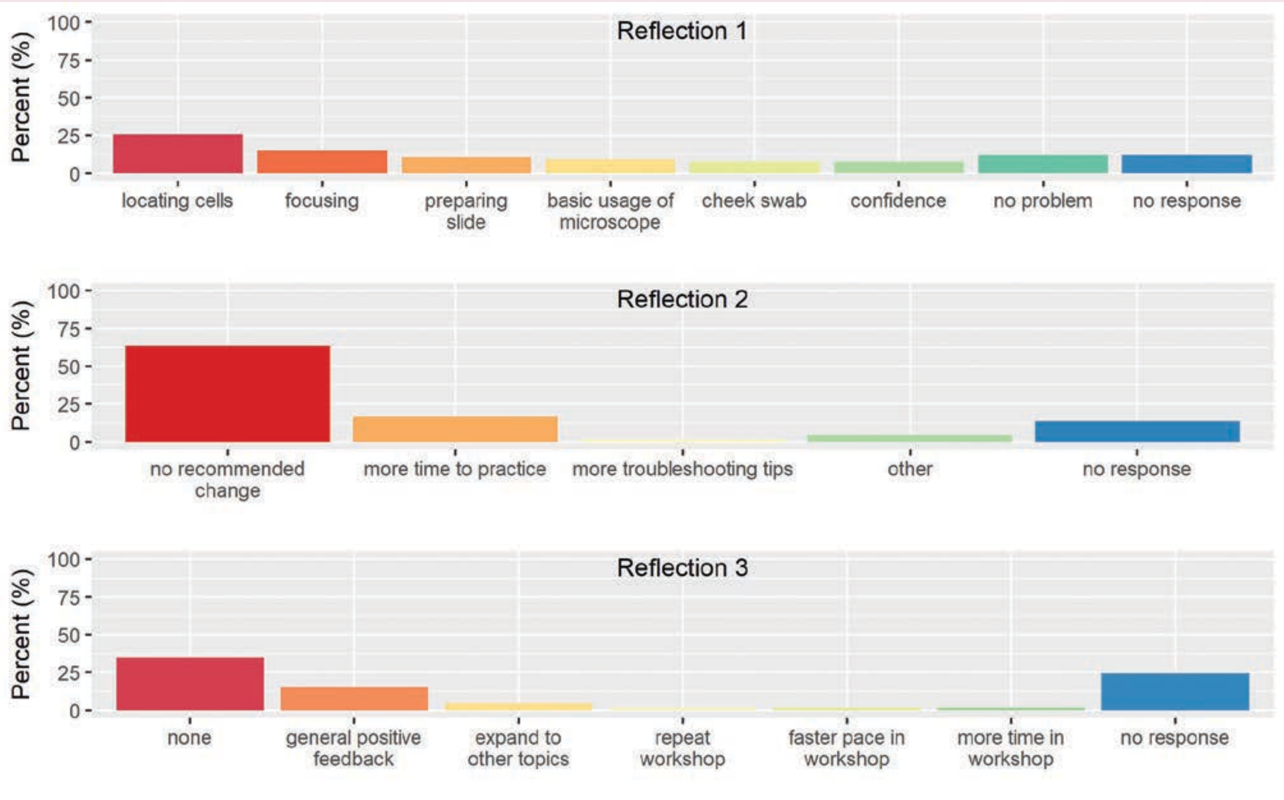


on overall course grades may be difficult to quantify, the apparent strong improvement in student confidence regarding their microscope skills is heartening. A variety of research has suggested that student success and confidence building in one area of their studies may lead to improved overall performance (Graham, Frederick, Byars-Winston, Hunter, & Handelsman, 2013; Wai, Lubinski, Benbow, & Steiger, 2010). Students new to college-level science courses are often taken aback by the pace, rigor, and sheer quantity of information presented, leading to feelings of helplessness (Ellis et al., 2016) and to the development of negative attitudes regarding their ability to succeed in their science education (Inkelas, 2011). The confidence developed in workshops such as ours may help students overcome feelings of helplessness and assist in the development of a positive attitude essential for success in their coursework (Strayhorn, 2015). Community college students struggle with their STEM identity (Toland, 2017), which can impede their progress and completion. STEM identity formation (Carlone & Johnson, 2007) requires three aspects: performance, recognition, and confidence. The microscope workshops give students the opportunity to see themselves perform well in science; to be recognized by themselves, peers, and faculty as competent in the use of the microscope; and to have confidence in their ability to use the microscope effectively.

Overall, we feel that microscope clinics such as those described in this article offer a cost-effective, easy-to-implement, and effective technique for improving student learning of a skill set of fundamental importance to success in life-science courses. The improved microscopy skills and, perhaps more important, confidence

FIGURE 3

Responses to reflection questions. Reflection questions were open-ended prompts that allowed students to write responses. Student responses were coded into five to eight categories on the basis of the main theme of the response. See Table 1 for more information on reflection prompts.



students acquire from our clinics will benefit them in General Biology I and all of their subsequent courses with relatively little investment of time or resources from faculty or the institution. Our only requirements were an open lab room with microscopes, slides, cover slips, dyes, Q-tips, cheeks, and a few hours of faculty time. In the future, we would like to examine the possible longer term impact of our clinics in terms of microscope skills demonstrated in later courses, student retention, and overall student success. Future analysis will include such data as well as student focus groups designed to assess clinic impact and areas for possible improvement in greater detail. ■

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