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ILLUMINATIONS

Active peer-mentored learning can improve student understanding of physiological concepts in an undergraduate journal club

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INTRODUCTION

Active learning (enabling students to actively participate in their learning as opposed to being recipients of passive information) is increasingly being integrated into most areas of undergraduate education (10, 12). The use of active learning to facilitate student understanding has been well documented in the specific disciplines of science, technology, engineering, and mathematics (STEM), where active learning has been shown to enhance student understanding of STEM concepts and decrease failure rates in STEM courses (10). Active learning can be encouraged by active teaching techniques, such as implementation of team-based learning classes that can produce higher examination scores in courses compared with those that rely on traditional lecture formats only (25). Furthermore, in addition to boosting summative assessment scores, active learning in STEM fields has also been associated with other benefits, such as increased student confidence and knowledge, enrollment retention, and a narrowing of the achievement gap for underrepresented minority groups (4, 11–13).

One of the most ubiquitous active learning modalities in research-focused biological sciences for the last ~150 yr has been the so-called "journal club" (15), whereby undergraduate or graduate students read and critically evaluate scientific articles, culminating in a presentation of their appraisal of the article delivered to student peers. As such, journal club provides a multitude of beneficial learning outcomes for students, such as an acquisition of critical reading skills to evaluate the scientific literature (5, 14, 18), improving their scientific literacy (8), introducing them to new concepts or techniques (3), and, importantly, improving student overall confidence (5) and communication skills (3, 8, 14, 15). Thus journal club, by allowing students to participate in the scientific process through critically evaluating the literature, encourages students to begin self-identifying as scientists and view themselves within a scientific learning community (11, 15, 17, 22). It is also well recognized that presentation and communication skills, which journal club promotes, are a vital part of general professional and academic success in all fields (23, 27).

Furthermore, journal club participation facilitates the types of higher order learning detailed in Bloom's Taxonomy that are vital to become a successful scientist (2, 6). In journal club, science students must be able to critically analyze and evaluate data and concepts and then apply their knowledge of these data to create a cohesive appraisal of the article, which they must then effectively communicate to their peers. Thus journal club affords students the opportunity to exercise many key skills required of professional scientists.

However, despite all of the perceived aforementioned benefits, it can be difficult for instructors who facilitate journal club to ascertain student audiences' understanding of the topics being related by presenters. Indeed, student audience members in journal club classes may appear to listen to and understand a presentation, but without an empirical assessment of their understanding at the conclusion of journal club, the pedagogical benefits of the session are impossible to know. Such assessments are essential so that appropriate interventions can be implemented to address gaps in students understanding.

At the University of Nevada, Reno School of Medicine (UNRSOM), an international undergraduate research program has been in place for the last 30 yr. In this program, international students in the life science undergo a 12-mo placement in various departments within UNRSOM to obtain hands-on experience in modern basic science methodologies. An integral component of the placement program is participation in a regular journal club module. However, as the effect of journal club on student learning of physiological concepts had not previously been empirically assessed, it was the aim of the present study to do so. We also sought to determine whether student understanding could be improved by complementing the standard journal club format with peer-mentored workshops.

METHODS

Student background. A total of 11 undergraduate students took part in the study. All students involved in the study were life science undergraduate students from universities from the islands of Ireland and Britain, with 3 students (all women) from Queens University Belfast and 8 students (6 women and 2 men) from The University of Manchester. These students came from a diverse group of nationalities, with students originating from Ireland, England, Luxembourg, Germany, and Poland. All students were placed in different laboratories in the Department of Physiology and Cell Biology or the Department of Pharmacology at UNRSOM for 12 mo. During this period, students undertook a program of intensive research under the direct supervision of a senior principal investigator.

Journal club presentation format. As part of their placement, students were required to participate in a regular journal club. Students took part in journal club every Friday afternoon during the fall (September–December 2017) and spring (January–June 2018) semes-

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ters. Journal club took place at 4 PM and lasted 45–60 min. All 11 students attended journal club, along with a faculty facilitator (the same every week, no additional faculty were present), and presented once during both the fall and spring semesters (twice total during their placement program).

Before their designated week to present at journal club (during each semester), each student selected a paper relevant to their area of research and was asked to read the paper in detail to acquaint themselves with its main concepts and techniques. The paper would also be forwarded to all other members of the group five days in advance of journal club to allow time for reading of the paper. During journal club, students would present the background of the chosen paper, explore the main findings, and critically evaluate the data and interpretations contained within each paper. Students were encouraged to ask questions during each presentation to clarify any areas of confusion, and this was assisted by the journal club faculty facilitator. Thus the journal club sessions facilitated more discussion of, and interaction with, the presented material than would occur in a traditional didactic lecture format.

Journal club topics/themes. The students were placed in research groups within the Department of Physiology and Cell Biology and the Department of Pharmacology at UNRSOM that emphasized the regulation of vascular and visceral smooth muscle excitability. Many laboratories in these departments study the role of interstitial cells in controlling the contractions of the gastrointestinal (GI) wall (9) and how smooth muscle contractility is controlled by Ca^{2+}-dependent mechanisms (26). Thus many of the papers presented at journal club brought students into contact with physiological concepts that were repeated several times. Themes and concepts that were repeatedly presented during journal club included the following: *1*) how smooth muscle contraction occurs; *2*) the role of Ca^{2+} in excitation-coupling; *3*) the role of interstitial cells in modulating the activity of the GI tract; and *4*) how resting membrane potential is formed and influenced by activation of different ion channels, and how this affects muscle contraction.

Regardless of the techniques or physiological concepts explored in a journal club session, the journal club faculty facilitator encouraged students to critically assess papers universally by examining key criteria for the validity of data. Examples of such criteria included the following: *1*) did the authors use appropriate controls? (vehicle/time controls); and *2*) does the data in the paper represent values from an adequate sample size?

Formative assessment of student understanding. To quantify student understanding of the aforementioned concepts explored in journal club sessions, they were asked to complete an anonymous formative assessment at the end of the fall semester, after all students had presented once. This formative assessment was designed by the journal club faculty facilitator and consisted of 11 questions (Q1–Q11; worth a total of 22 points), which touched on important experimental and physiological concepts that were presented during the preceding 11 wk of journal club. The formative assessment evaluated students understanding of the following topics:

Q1: Vehicle controls (1 point)
Q2: Voltage-dependent excitation-contraction coupling (3 points)
Q3: Appropriate experimental replicates in data sets (1 point)
Q4: Ca^{2+}-dependent excitation-contraction coupling in muscle (2 points)
Q5: Confocal microscopy (1 point)
Q6: Intestinal motility (2 points)
Q7: Resting membrane potential (6 points)
Q8: Global knockout mouse models (2 points)
Q9: Inducible knockout models (1 point)
Q10: Cre-Lox P technology (1 point)
Q11: Electrophysiology and relationship of voltage and current (2 points)

Students completed the quiz in 30–50 min alone without conferring with other students. The scores of all 11 student quizzes were then tabulated as a percentage score.

Active peer mentored presentations. After marking, any questions from *test 1* that had been answered poorly (indicating a lack of student understanding in those areas) were noted and designated for intervention. Thus, to improve student understanding of these areas, students were organized into pairs before the spring semester of journal club and asked to develop a peer-mentored presentation on an area highlighted by low scoring in *test 1*. These peer-mentored presentations consisted of six different topics, with each student pair assigned to one presentation (with the exception of a single student who was assigned by random draw to work on two presentations, due to the odd number of students in the group). The topics covered by students in these presentations were as follows:

1. Appropriate experimental controls
2. Cellular contractility
3. Electrophysiology
4. Ca^{2+}-dependent regulation of smooth muscle contraction
5. Interstitial cells in the GI tract
6. Cre-Lox P techniques.

Each session lasted 30 min and included a 15-min presentation from both students, who had to contribute equally; audience question and answer was encouraged throughout these presentations. The presentations were then followed by a 15-min question-and-answer session, in which the presenters asked questions of the audience to ascertain if they understood what had just been presented to them. Two such sessions were performed from 4 to 5 PM on a Friday afternoon for 3 consecutive wk, before regular journal club, as described above, resumed, with each student presenting a paper once during the spring semester (January–June 2018). At the conclusion of the spring semester journal club schedule (June 2018), students were asked to complete the same formative assessment that they completed in December 2017. Students were not told that they would be asked to complete the same formative assessment again ahead of time. The results from this second quiz (*test 2*) were then calculated as a percentage score.

The scores of both tests (before and after peer mentoring) were compared using GraphPad software using an unpaired Student *t*-test with Welch's correction (comparison of mean score) and also with a nonparametric Mann-Whitney test (comparison of the distribution of all score values). P values < 0.05 were taken as significant for all statistical tests. An unpaired *t*-test was used, as both formative assessments were anonymous, and thus it was not possible to directly compare the results of one student over both the fall and spring semesters without losing student anonymity. The results of both tests were not revealed to students until all results were tabulated, at which point the journal club faculty facilitator presented the results of both tests, along with a detailed tutorial on the questions asked in the formative assessment.

After the completion of the second semester, all students completed an anonymous five-item survey of their experience with journal club and the peer-mentored workshops and how these impacted their learning throughout both semesters. *Items 1–3* in this evaluation were assessed on a Likert scale (strongly disagree, disagree, don't know, agree, strongly agree): "The peer-mentored workshop implemented in January 2018 enhanced my understanding of physiological concepts and techniques encountered in journal club" (Q1); "The peer-mentored workshop in January 2018 contributed to my ability to answer questions correctly in the assessment taken in Summer 2018" (Q2); and "I felt better prepared for journal club following the peer-mentored workshops" (Q3). The fourth question (Q4) was a binary choice: "Which semester of journal club was of most benefit to your learning: *semester 1* (without workshops) or *semester 2* (with workshops)? Examples of learning can include, but are not limited to, presentation skills, scientific literacy, ability to critically evaluate data, ability to discuss science with peers, confidence in handling difficult or critical questions." The final survey

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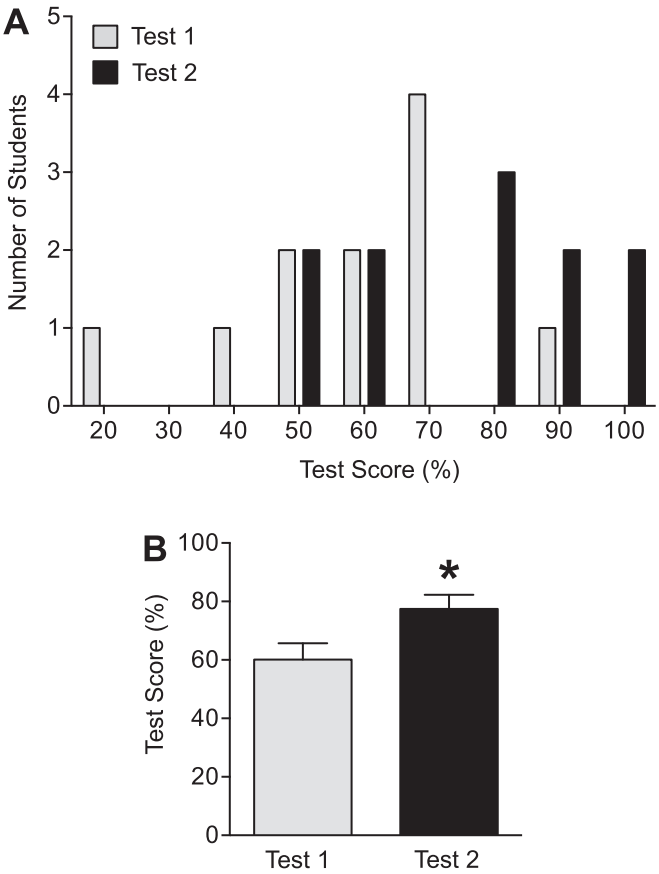

Fig. 1. Distribution of student scores in *test 1* and *test 2*. *A*: frequency distribution showing the scores (%) of all 11 students from the completed assessment for *test 1* (shaded bars) and *test 2* (solid bars). *B*: summary data comparing the mean score (%) of all students for *test 1* (shaded bars) and *test 2* (solid bars). $n = 11$ Students. *$P = 0.03$.

item (Q5) was open ended: "Please provide any further comments about journal club or the peer-mentored workshop that you feel are relevant (positive or negative)."

RESULTS

As shown in Fig. 1, the mean score for all 11 students in the first formative assessment (*test 1*) was 60.1 ± 5.6%. The minimum score was 22.7%, and the maximum score was 90.9%. The distributions of all scores in *test 1* are shown as a frequency histogram (shaded bars) in Fig. 1*A*. Based on these results and specific questions answered correctly/incorrectly, areas in need of intervention were identified, and peer-mentored workshop presentations were used to facilitate student learning in these areas, as described in METHODS.

After completion of the peer-mentored workshop presentations at the onset of the second semester, each student presented in journal club once during the spring 2018 semester. At the conclusion of the spring 2018 semester, students were asked to complete the same formative assessment they attempted in December 2017: it was not revealed to students beforehand that they would be asked to complete this same formative assessment. As before, the formative assessment was anonymous and graded using the same marking scheme as for *test 1*.

The student scores from this second formative assessment (*test 2*) were significantly enhanced compared with *test 1*. The distribution of student scores in *test 2* is shown as a histogram in Fig. 1*A* (solid bars), and this distribution of values was found to be statistically different from those in *test 1* ($P = 0.028$; Mann-Whitney). We also analyzed the mean change in student score between the different assessments. The mean score for *test 2* was 77.5%, an increase of 17.4%, which was found to be a statistically significant increase (Fig. 1*B*, $P = 0.03$, unpaired *t*-test). Also, it is worth noting that the minimum student score in *test 2* was 54.6%, which was a 31.8% increase from the minimum score in *test 1* (22.7%). The maximum score also increased between *tests 1* and *2*, rising from 90.9% (attained by a single student) in *test 1* to two students attaining perfect 100% scores in *test 2* (Fig. 1*A*).

As shown in Fig. 2, in the end of the program survey, all students responded positively to Q1–Q3 (described in METHODS and Fig. 2). When asked if the peer-mentored workshops positively affected their conceptual understanding of physiological concepts encountered in journal club, 100% of students selected "strongly agreed" or "agreed" (Fig. 2, Q1). One hundred percent of students also selected "strongly agreed" or "agreed" when asked if the peer-mentored workshops contributed to their ability to successful complete the formative assessment in the spring semester (Fig. 2, Q2). All students also selected "strongly agreed" or "agreed" when asked if the peer-mentored workshops better prepared them for journal club (Fig. 2, Q3). When asked which semester of journal club was of most benefit to their learning, the majority of students (81.8%) selected *semester 2* (with workshops, Fig. 2, Q4). The full responses to the open-ended question for feedback on journal club and the peer-mentored workshops are presented in the APPENDIX.

DISCUSSION

In the present study, we sought to quantify student understanding of physiological concepts in an undergraduate journal club and set out to also determine whether student understanding could be improved by complementing the standard journal club format with peer-mentored workshops. The first formative assessment conducted at the end of the fall semester demonstrated that student learning in journal club was initially somewhat limited. This finding led to the inclusion of an intervention to enhance active learning in journal club. We chose to utilize peer-mentored workshops for this purpose, as the use of peer mentoring has been noted to instill many benefits in student learning, such as promoting facilitative learning (16), decreasing student anxiety (as they are working with a peer and not afraid of appearing to be "wrong" to an authority figure) (19, 20), and promoting improved general exam performance in STEM courses (4, 7). Interestingly, peer mentoring also enhances student understanding of STEM concepts, even if, at the onset, no student within the group knows the correct answers or grasps the key facts (24). Thus peer mentoring appears to be a highly valuable approach to narrowing gaps in understanding that may occur across large proportions of students. It has been shown through student evaluations and quantification of assessment scores in both undergraduate and graduate level biology/medical courses that peer-mentored workshops can dramatically enhance student engagement and learning (13, 21), increase graduation rates, and reduces failure rates in STEM courses (1, 13).

We found that, after implementation of an active learning intervention (peer-mentored workshops), student understanding of general experimental and physiological concepts signif-

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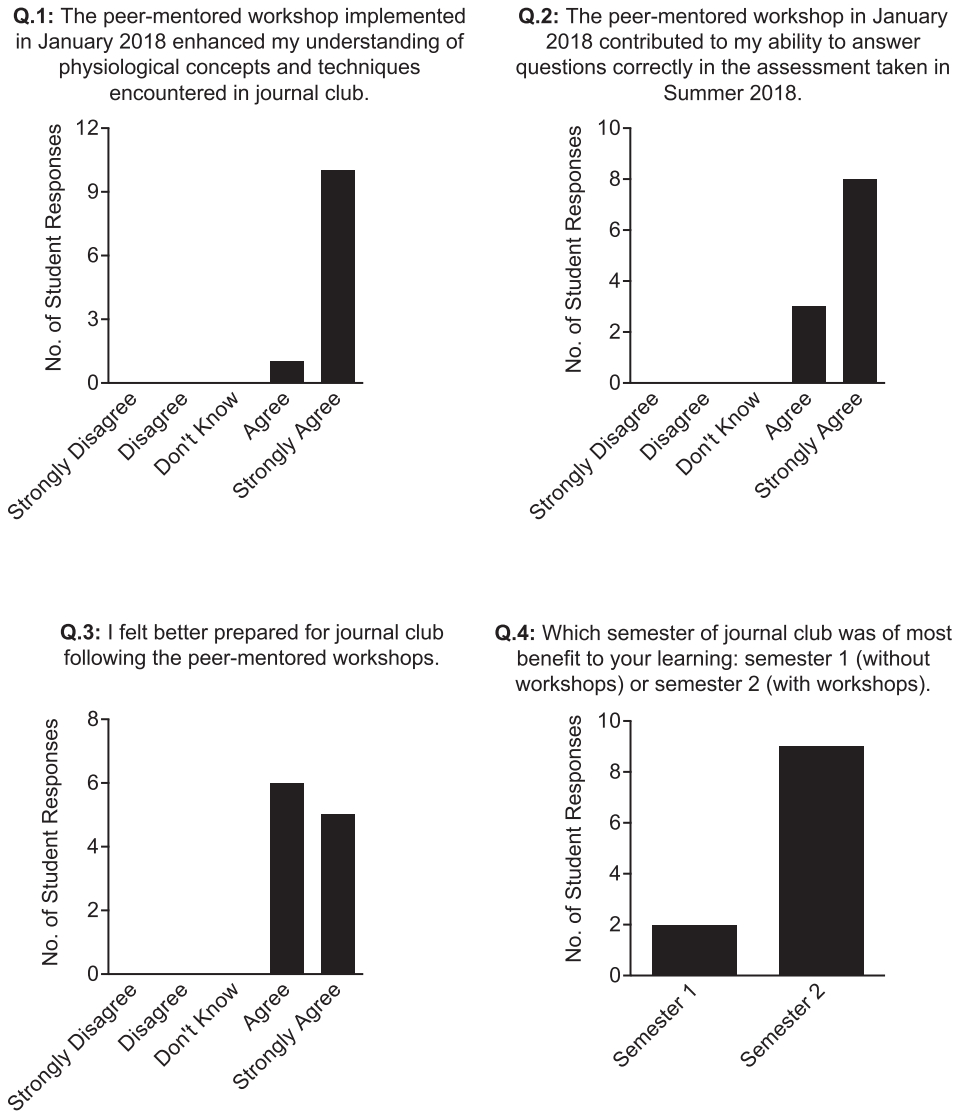

Fig. 2. Student evaluation feedback. Summary data showing student responses for *questions 1–4* (Q1–Q4) on the student self-evaluation form completed by all students at the conclusion of the academic year. $n = 11$ Students.

icantly increased, as assessed by our formative assessment. Taken together, our data suggest that appropriate active learning interventions, such as peer-mentored workshops, can be a useful approach to enhancing student understanding of general scientific and physiological concepts within an undergraduate journal club program. Similar to journal club, peer mentoring places the responsibilities of learning and teaching commitments directly onto students. As such, students must take ownership of the material so that learning can occur (16). While in traditional journal club sessions this responsibility is endowed solely on the student presenting, peer mentoring facilitates cooperative learning and enhances the sense of a learning community. Our data from this case study suggest that this peer-mentored workshop approach may be a valuable addition to traditional journal club classes.

One limitation of this study was that it was not possible to control for factors other than the peer-mentored workshops that may have led to an increase in student scores in the second formative assessment. It is possible that, as the formative assessment was not changed between tests, students may have been "primed" to those questions and, therefore, in a better position to answer them correctly the second time around. However, the use of a different formative assessment for the second assessment would not have led to a like-for-like comparison, and thus the same formative assessment was chosen to afford more consistent interpretations of student scores. Furthermore, we suggest that, as a copy of the formative assessment was not provided to students beforehand (or afterwards), combined with the fact that students completed the tests a full 6 mo apart, students were unlikely to be fully "primed" to the formative assessment questions for *test 2*. Despite this limitation, evidence from the student evaluations completed at the end of the year suggests that the implementation of the peer-mentored workshop was a major factor in the increase in student scores between the two semesters.

In their evaluation, when asked the open-ended question in their evaluation—"Please provide any further comments about journal club or the peer-mentored workshop that you feel are relevant (positive or negative)"—many students commented that the use of the workshops greatly increased their confidence in presenting scientific data, participating in peer review, and handling critical questions. This was also evidenced by the fact that all students at least agreed with the statement, "I felt better prepared for journal club following the peer-mentored work-

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shops." In fact, in the open-ended request for feedback on journal club and the workshops (Q5), many students stated that the workshops were so beneficial (enhanced scientific literacy, increased confidence in presenting, reading papers) that they proposed that similar workshops should be conducted at the very start of the academic year to "kick start" the learning process in the first semester for future students. Some of this feedback from students included statements such as, "Workshops should first be done at the start of the year to give everyone a basic understanding of the topics that will be discussed throughout the year," whereas another student commented

> I think that it would be beneficial to have the workshops at the start of the year as a lot of us had never studied electrophysiology before and, therefore, most of the concepts were new, which made presenting an entire paper related to the subject quite challenging. I definitely felt more confident presenting papers after the workshops.

There was also a common positive appraisal of journal club in general, with students commenting that it helped with their scientific literacy, typified by one student stating,

> All together, the journal club helped with reading research papers properly and understanding how to critically evaluate it, which is really important. I do not find reading research papers as difficult anymore.

Another common theme was that students commented that journal club had made them more confident with delivering presentations in general:

> We have done numerous presentations already this year, but I feel much more confident going into them and also more confident in my ability to answer questions.

Thus, whether relating to scientific literacy or communication in general, there was a common thread of increased confidence in the students after the peer-mentored workshops. Further studies should pursue this observation to determine other modalities that may facilitate increased student confidence in undergraduate classes. Overall, the feedback suggested that the increase in formative assessment student scores was at least partially due to the positive effects of the peer-mentored workshops, and that students overall found such workshops beneficial in enhancing their learning experience within the journal club module.

In conclusion, data from this case study suggest that, by allowing students to undergo peer-mentored learning in conjunction with journal club sessions, student understanding of physiological concepts, as well as student confidence in presenting and communication, increases.

APPENDIX

Student Responses to Survey Q5: "Please provide any further comments about journal club or the peer-mentored workshop that you feel are relevant (positive or negative)."

1. "Journal club has provided me with several sets of skills including data analysis, presentation of my own data and how to critique data to know what's good and not so good."
2. "I like that the workshop PowerPoints were circulated around the group as I still use them to review certain areas. Both the workshops and journal club have really helped me with presentation skills, it enabled me to get away from scripting my presentations and I think I am a much better presenter because of that as it flows much better. It set us up very well for the end of year symposium and also for final year. We have done numerous presentations already this year but I feel much more confident going in to them and also more confident in my ability to answer questions. I did find it very difficult to get up and present to my peers at the beginning but it was something I needed to learn to deal with and it has been of great benefit to me this year."
3. "Workshops should first be done at the start of the year to give everyone a basic understanding of the topics that will be discussed throughout the year."
4. "Good structure to journal club, helped my learning and broadened my knowledge on other fields not just my own. Greatly helped with end of year symposium."
5. "I really enjoyed the variety of things we did in the journal club, e.g. presentations (alone or in groups), critically evaluating papers and receiving feedback on our own data. Overall, very enjoyable and beneficial!"
6. "All together, the journal club helped with reading research papers properly, and understanding how to critically evaluate it. Which is really important. I do not find reading research papers as difficult anymore."
7. "The journal clubs were great, they were very professional and definitely helped me develop scientific thinking. They also helped me improve presentation skills and the ability to explain complex scientific mechanisms in a straightforward way. Establishing people's levels of knowledge at first (e.g. through workshops) before moving into papers would be a great order for organizing journal clubs."
8. "It was a good experience and I strongly recommend it in order to improve our understanding of physiological research, especially because most of us were not familiar with it previously."
9. "I think that it would be beneficial to have the workshops at the start of the year as a lot of us had never studied electrophysiology before and therefore most of the concepts were new which made presenting an entire paper related to the subject quite challenging. I definitely felt more confident presenting papers after the workshops! Overall journal club has been invaluable in improving my presentation and analytical skills."
10. "Journal club was a great way to get used to presenting and discussing research and was a very valuable thing to do. The workshops were beneficial and would be good to have at the beginning of the year. One improvement that could be made is that the journal clubs tend to be focused on the SIP syncytium/smooth muscle when there are some students who don't work on that. It might be good if their workshop could feature some of the scientific background/techniques from their work in more detail."
11. "I found the peer-mentored workshops very beneficial and believe that they may be more useful for future students to start with. Overall journal club was great and I always looked forward to it!"

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DISCLOSURES

No conflicts of interest, financial or otherwise, are declared by the authors.

AUTHOR CONTRIBUTIONS

B.T.D. conceived and designed research; B.T.D. performed experiments; B.T.D. analyzed data; B.T.D., M.G.R., and S.M.W. interpreted results of experiments; B.T.D. prepared figures; B.T.D. drafted manuscript; B.T.D., M.G.R., and S.M.W. edited and revised manuscript; B.T.D., M.G.R., and S.M.W. approved final version of manuscript.

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