Tips and Tools

JMBE Journal of Microbiology & Biology Education

A Team-Based Activity to Support Knowledge Transfer and Experimental Design Skills of Undergraduate Science Students

Lisa M. D'Ambrosio[a]

[a]*Department of Biochemistry, Microbiology and Immunology, Faculty of Medicine, University of Ottawa, Ottawa, Ontario, Canada*

KEYWORDS experimental design, peer feedback, team-based learning, knowledge integration, research proposal, knowledge transfer

INTRODUCTION

A central learning objective of undergraduate science education is to enhance students' critical reasoning and experimental design skills (1, 2). Development of these competencies requires students to have opportunities to practice identifying problems, generating focused hypotheses, creating experimental models, and anticipating data outcomes. Experimental design also demands that students are able to effectively transfer and apply knowledge from previous learning experiences to novel contexts, a skill that serves as a persistent challenge for science undergraduates (3, 4). Instructional strategies that offer students opportunities to interleave concepts and to actively engage with their learning may enhance knowledge transfer and academic performance in the undergraduate sciences (3, 5). This active-learning exercise, therefore, uses a combination of team-based peer review and collaborative discussions to strengthen students' skills in experimental design and transfer of knowledge in the undergraduate sciences (6–9).

This team-based exercise is designed for upper-level undergraduate science courses of 50 or fewer students and may be conducted via in-person or virtual formats. By the end of this activity, the learner should be able to (i) have a fundamental understanding of how to design a controlled experiment, (ii) evaluate the strengths and areas of improvement of experiment proposals, and (iii) identify how diverse scientific concepts from prior learning experiences apply to novel experiment-based problems.

Editor Megan Barker, Simon Fraser University
Address correspondence to Department of Biochemistry, Microbiology and Immunology, Faculty of Medicine, University of Ottawa, Ottawa, Ontario, Canada. E-mail: ldambros@uottawa.ca.
The author declares no conflict of interest.
Received: 17 January 2022, Accepted: 22 April 2022,
Published: 4 May 2022

PROCEDURE

Activity format

The flexible design of this activity allows for adaptation to a variety of course schedules and delivery modes and may be conducted once or multiple times during a term. Suggested timelines for delivery are provided in Appendix 1. The activity requires the instructor to organize students into teams of 4 to 5 learners prior to the activity start date. Each team then completes the activity via four consecutive steps (proposal drafting, peer review, proposal revision, and class discussion), each of which is discussed below (Fig. 1).

Proposal drafting

The activity begins with each team receiving a focused research question to serve as the basis for their proposal (see Appendix 1 for question examples). The instructor may assign the same or different research questions to the teams, or the teams may be invited to generate their own research questions. Team members are then given a designated amount of time (i.e., according to one of the timeline schedules suggested in Appendix 1) to complete an experiment proposal template (Appendix 2). This proposal requires each team to (i) state the research question, (ii) design a controlled experiment to address the research question, (iii) indicate how the data will be analyzed, (iv) illustrate the various predicted outcomes, and (v) describe how the experiment integrates knowledge from previous learning experiences. Regarding the latter, the proposal requires teams to describe how at least 2 concepts (i.e., theory, technique, etc.) learned in previous courses are illustrated in the theoretical and/or technical aspect(s) of the experiment plan. Instructors are encouraged to use the proposal template as a guide to provide learners with a brief (20 to 30 min) in-person or recorded tutorial on the expectations for drafting effective experiment proposals prior to initiation of this exercise.

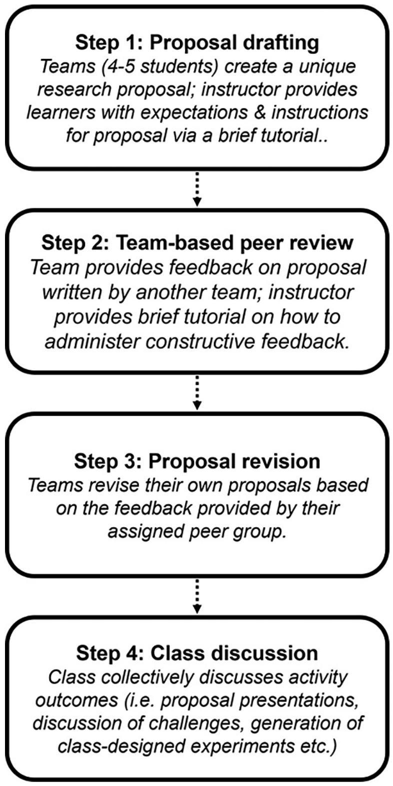

FIG 1. The sequential steps of the experiment design activity.

Peer review

Once proposals have been drafted, each team will have the opportunity to review one proposal prepared by another team. The instructor may randomly match the teams into pairs whereby the pair groups swap proposals for their peers to review. Each team pairing may be assigned a designated space on the course learning management system to facilitate sharing of documents. Within a specified time frame (Appendix 1), each team is then expected to provide feedback on their peer group's proposal by using a peer review evaluation template (Appendix 3). This template requires learners to assess the overall strengths and areas for improvement of the experimental plan, and it also requires teams to provide additional insight into how the experiment demonstrates integration of prior knowledge. Teams are encouraged to use editing tracking features on their word-processing programs to directly provide edits and constructive feedback. Teams then submit the completed evaluation template and edited proposal to their respective pair group and to the instructor via the course learning management system. Teams will be assessed by the instructor on the quality of peer feedback (see "Evaluation" for details). Prior to initiating the peer review process, instructors are encouraged to provide learners with a brief (20 to 30 min) tutorial on how to provide fair and constructive feedback to support peer learning using the peer review evaluation template as a guide.

Proposal revision

Teams are then provided with a specific amount of time (Appendix 1) to revise their experiment proposals based on the feedback received from their peer group. Teams then submit their revised proposals via the course learning management system for evaluation by the instructor (see "Evaluation" for details).

Class discussion

Once proposals have been revised and submitted, the class may meet as a collective unit to discuss key outcomes of the activity. For example, the class discussion may involve (i) proposal presentations by volunteer team groups, (ii) discussion of the benefits and challenges of experiment design/proposal writing, (iii) prediction of experiment outcomes of different team proposals, (iv) discussion on the importance of knowledge transfer (i.e., understanding how connections between disciplines can enhance experiment planning), and (v) practice applying new skills by collectively designing a class experiment(s) based on a new research question.

Evaluation

Evaluation of this activity includes three points of assessment. The first assessment evaluates the completeness and quality of feedback provided by each team on their peer group's proposal. The second assessment evaluates the completeness, quality, and evidence of knowledge integration of the final experiment proposal submitted by each team. The instructor may evaluate these two points of assessments by using the respective marking rubrics (Appendix 4). A single mark is assigned to each group for each of these two assessments. Lastly, each student is expected to complete a confidential peer-evaluation form (Appendix 4) for each member of their team after final proposals have been submitted. These peer-evaluation forms are submitted directly to the instructor via the course learning management system, and the average of the peer-evaluation marks may be calculated for each team member. The first two instructor-graded assessments may represent a larger weight of the student's overall activity mark relative to that of the average of peer-evaluation grades.

CONCLUSION

Altogether, this collaborative team-based activity aims to strengthen learners' capacity to design focused experiments, to accurately anticipate data outcomes, and to ultimately recognize how transfer of prior knowledge may support creative solutions to research problems in science-related fields. This activity may also be adapted for alternative applications to support diverse learning objectives such as writing of literature reviews, critique of published experiments, or design of scientific posters and seminars.

SUPPLEMENTAL MATERIAL

Supplemental material is available online only.
SUPPLEMENTAL FILE 1, PDF file, 0.3 MB.

ACKNOWLEDGMENT

The author declares no conflict of interest.

REFERENCES

1. Coil D, Wenderoth MP, Cunningham M, Dirks C. 2010. Teaching the process of science: faculty perceptions and an effective methodology. CBE Life Sci Educ 9:524–535. https://doi.org/10.1187/cbe.10-01-0005.
2. Dowd JE, Thompson RJ, Schiff LA, Reynolds JA. 2018. Understanding the complex relationship between critical thinking and science reasoning among undergraduate thesis writers. CBE Life Sci Educ 17:ar4. https://doi.org/10.1187/cbe.17-03-0052.
3. Kaminske A, Kuepper-Tetzel CE, Nebel CL, Sumeracki MA, Ryan SP. 2020. Transfer: a review for biology and the life sciences. CBE Life Sci Educ 19:es9. https://doi.org/10.1187/cbe.19-11-0227.
4. Newman DL, Catavero CM, Wright KL. 2012. Students fail to transfer knowledge of chromosome structure to topics pertaining to cell division. CBE Life Sci Educ 11:425–436. https://doi.org/10.1187/cbe.12-01-0003.
5. Freeman S, Eddy SL, McDonough M, Smith MK, Okoroafor N, Jordt H, Wenderoth MP. 2014. Active learning increases student performance in science, engineering, and mathematics. Proc Natl Acad Sci U S A 111:8410–8415. https://doi.org/10.1073/pnas.1319030111.
6. Odom S, Glenn B, Sanner S, Cannella KAS. 2009. Group peer review as an active learning strategy in a research course. Teach High Educ 21:108–117.
7. Linton DL, Farmer JK, Peterson E. 2014. Is peer interaction necessary for optimal active learning? CBE Life Sci Educ 13:243–252. https://doi.org/10.1187/cbe.13-10-0201.
8. Nicol DJ, Macfarlane-Dick D. 2006. Formative assessments and self-regulated learning: a model and seven principles of good feedback practice. Stud High Educ 31:199–218. https://doi.org/10.1080/03075070600572090.
9. Campbell CG, Taylor TZ. 2020. Assessing student learning and knowledge transfer using principles of team-based learning and bridge assignments in large introductory statistics classes. Scholarsh Teach Learn Psychol 6:15–23. https://doi.org/10.1037/stl0000167.