# The Whole is Greater than the Sum of the Parts: A Research Poster Project Provides an Integrative Framework for Learning Across Foundation Courses in Biology

Ahmed Elbassiouny[1,2], Paolo DiSordi[2], Sarah Guay[3], Angela Hamilton[4], Sarah King[4], Jason Brown[2], Peter Molnar[2], Maydianne C.B. Andrade[2], C. Dan Riggs[2], Ivana Stehlik[2] and Aarthi Ashok[2] *

[1]Department of Cell and Systems Biology, University of Toronto, 25 Harbord Street Toronto, ON Canada M5S 3G5.

[2] Department of Biological Sciences, University of Toronto, Scarborough, 1265 Military Trail, Toronto, Ontario, M1C 1A4, Canada.

[3]UTSC library, 1265 Military Trail, Toronto, Canada.

[3]Liaison librarians for Biological Sciences, UTSC library, 1265 Military Trail, Toronto, Ontario, M1C 1A4, Canada.

[4]Writing Centre, UTSC, 1265 Military Trail, Toronto, Ontario, M1C 1A4, Canada.

*Corresponding author.

**Abstract**

The integration of ideas, defined as the process by which students organize and connect new knowledge for deeper understanding, is essential for lifelong learning. (Government of Canda, Employment and Social Development Canada, 2017; Rateau, Kaufman, & Cletzer, 2015). Integration across sub-disciplines in biology requires an understanding of organizational scales (molecular to ecosystems) and time frames (physiological to evolutionary), and how they inter-relate. The challenge lies in allowing students opportunity to integrate knowledge, given that sub-disciplines are taught in relative isolation through individual courses. To promote integration, we designed a poster assignment in which ~700 students in three foundation courses worked together (130 groups) to investigate empirical research in multiple sub-disciplines. While a major goal was to enrich understanding by integrating knowledge, we also sought to develop transferable skills (e.g. teamwork, information literacy). Hence, this cross-course assignment provides benefits that exceed that of equivalent assignments in individual courses; we believe that *the whole is greater than the sum of the parts*. Assignment grades indicated that the majority (81%) of students successfully met or exceeded our expectations. This assignment lends support to the positive impact of learning communities, is easily adapted to other disciplines, and aligns with calls for educational reform advocating for curiosity-driven learning (American Association for the Advancement of Science, 2011; Bradforth et al., 2015).

**Keywords:** research poster assignment, foundation courses, teamwork, scientific communication, knowledge integration, information literacy, learning communities.

## Introduction

Creating curricular learning communities in which students co-enrolled in multiple courses work collaboratively on a learning activity, has been shown to enhance student engagement, fostering both academic and social connections among students (Kingston, MacCartney, & Miller, 2014; Kuh, 2003). Such communities in biology courses align with a constructivist approach to knowledge acquisition (Cakir, 2008); students are encouraged to pursue their own line of scientific inquiry to *construct* their understanding of a topic by connecting new ideas to existing knowledge, while using peers to support their learning. There is significant evidence that argues for the importance of collaborative group projects in stimulating deep learning (Tanner, Chatman, & Allen, 2003; Walton & Baker, 2009). We believe that engaging in collaborative teamwork is essential for students to hone interpersonal skills and gain experience in resolving group dynamics challenges, skills critical to students' academic performance and career success beyond university. Drawing inspiration from the evidence based on learning communities, our goal was to design an assignment in which students work collaboratively to integrate knowledge from different sub-disciplines of biology to create a research poster on a topic of interest to the group. As advocated for by educational reformists such as Weimer (2013), this assignment places the responsibility of learning on student groups, shifting the role of instructors to that of facilitators in a student-centered learning environment.

**Learning goals:**

The learning goals for the research poster assignment are listed here and we elaborate on the rationale for each below.

1. Integrate knowledge across various biological sub-disciplines.
2. Communicate scientific concepts and ideas effectively in both oral and written forms.
3. Work collaboratively with diverse group members while managing workload, time, and group dynamics.
4. Acquire information literacy skills (such as searching, evaluating, and critically reading scientific sources) and academic skills (such as formulating research questions, thinking critically and creatively, and respecting academic integrity).

1. **Integration of knowledge**

Studies examining learning communities show that integration of concepts leads to enhanced conceptual frameworks and deeper learning (Chaplin & Hartung, 2012). Hence, a major goal of this assignment was to allow students to recognize and highlight the links between different sub fields of biology. This would allow them to gain some experience in the cross-disciplinary nature of scientific inquiry and importantly, avert inert knowledge building that results from teaching in disciplinary silos. It was our goal to encourage students to explore a topic in biology for which insight can be gained by considering empirical research from at least two different fields of study (as represented by the six required, second year undergraduate courses in the Department of Biological Sciences at the University of Toronto, Scarborough (UTSC)). This assignment was designed as a mandatory component of each of three, required second year (known as B-level at our institution) courses in each of the Fall and Winter semesters (see note). Students registered in any of the three courses in each semester were grouped together for this assignment, allowing us to maximize the benefits to students enrolled in core courses with distinct disciplinary learning goals that nonetheless shared skill development goals (such as knowledge integration, communication etc.). As per this design, successful posters will pose an interesting question, clearly and concisely outline evidence from the primary literature in (at least) two different fields, and effectively communicate how integrating knowledge from these fields enhances understanding of their topic.

2. **Communication**

The effective communication of information to an intelligent, but naïve, audience is a critical skill in many professions. Professional communication may take many forms, from informal to formal, and also demands that the ideas being presented are supported by evidence, so that the audience receiving the information can properly assess the merit of the ideas. It has been shown that one of the reasons why teamwork is so desirable for university students is because of the substantial gains in communication skills that can be attributed to collaborative work (Oakley, Hanna, Kuzmyn, & Felder, 2007; Riebe, Girardi, & Whitsed, 2016). Hence, helping student teams develop scientific communication skills by creating an informative scientific poster was a major learning outcome for our assignment. Similar group project approaches have been successfully employed to promote communication skill development, albeit within individual courses (Walton & Baker, 2009). In requiring students to create a poster containing both text and pertinent visual images, it was our hope that students would also become more proficient at evaluating visual information presented in scientific articles.

3. **Teamwork**

The ability to work well as part of a team is an essential transferable skill for future employment of university graduates (Riebe et al., 2016). Productive teamwork is also indispensable to research groups and collaborative efforts in biology (Gibert, Tozer, & Westoby, 2017). Knowing how to deal with any issues that may

Note: Fall term curses: Cell Biology, Animal Physiology, Ecology
Winter term courses: Molecular Aspects of Cellular genetic processes, Plants& Society, Evolutionary Biology

arise as part of a team and understanding what personal strengths one brings to teamwork are students who work in teams, especially at large academic institutions, achieve higher academic performance, with significant benefits to their mental health and social integration (Roseth, Johnson, & Johnson, 2008; Strom & Strom, 2011). We were sensitive to student perspectives reported in the literature that suggested that social loafing (or "free riding") is one of the factors that govern their trepidation towards team projects (Gottschall & Garcia-Bayonas, 2008). Hence, we provided resources and a dedicated tutorial on effective teamwork and dealing with group dynamics issues, checked in with groups that reported group dynamics issues and created an explicit social loafing penalty (a penalty of up to 5 of the 10% value of the assignment) that could be applied by the teaching assistant (TA) and instructors, as we deemed fair in individual cases. There is evidence that students sort into homogenous groups (typically based on perceived academic ability, which may correlate with other demographic factors) when allowed to self populate teams for collaborative work (Freeman, Theobald, Crowe, & Wenderoth, 2017). While there are arguments for and against homogenous groups in biology courses (Jensen & Lawson, 2011; Manske, Hecking, Hoppe, Chounta, & Werneburg, 2015)(see note), we chose to constitute teams randomly in order to reflect the demographic and academic diversity of our student population.

4. **Information literacy**

Effective communication in the sciences requires proficient information literacy skills, which is also a key facet of lifelong learning (Crawford, Irving, Higgison, & Foreman, 2013). We see this as students' ability to mine databases, identify appropriate sources, evaluate the information presented in these sources and cite such sources accurately in their written synthesis (standards of the ACRL Information Literacy Network: http://www.ala.org/acrl/sites/ala.org.acrl/files/content/issues/infolit/framework1.pdf). We scaffolded this assignment with online scientific information literacy modules developed by liaison librarians at UTSC and assessed students' basic understanding and ability to mine the literature through an online quiz. The librarians and our colleagues at the Writing Centre generated a dedicated online research guide for the assignment, which included concise information on topics such as brainstorming keywords, critical to becoming a good team player. It is no surprise that large-scale studies have found that formulating research questions, citation management and plagiarism. It was our goal to help students become more confident in their ability to identify, seek and use necessary information from scientific sources and as a result become comfortable with the authentic research discourse of biology. As reported by others, we hoped this type of skills instruction would improve the quality of student-led research (Kingsley et al., 2011; Stevens & Campbell, 2008).

**Assignment structure:**

An information document for this assignment that included learning goals, details of the scaffolding, support, weekly expectations and final assessment was provided to students at the beginning of each academic semester (see Supporting Materials). Figure 1A is an infographic that summarizes the expectations and general assignment structure. Figure 1B provides a breakdown of various mini-deadlines and deliverables that students were required to complete over the 12-week timeline of the assignment

The model required coordination between course instructors, including scheduling of joint tutorials and scaffolding sessions for students enrolled across the three courses in each semester. We provide further details of the assignment elements and logistics below.

1. **Scaffolding tutorials**: We began with a tutorial in week 2 that set out the expectations for the assignment. Students had the opportunity to ask questions and learn about the supports available to them during the semester. A second scaffolding tutorial in week 3 involved meeting teammates and engaging in team building activities to identify different academic strengths and personal traits of their teams. Faculty presented some ideas on effective group processes and how to address group dynamics issues that may arise. Notably, we communicated the importance of building teamwork skills both for academic and future career success. In week 5, we held an unstructured tutorial in which groups could consult with faculty and the TA about any questions around topic selection. In weeks 8 and 11, unstructured group work tutorials allowed students to gather as a team in a large lecture hall (>450 student capacity), providing

Note: Fall term curses: Cell Biology, Animal Physiology, Ecology
Winter term courses: Molecular Aspects of Cellular genetic processes, Plants& Society, Evolutionary Biology

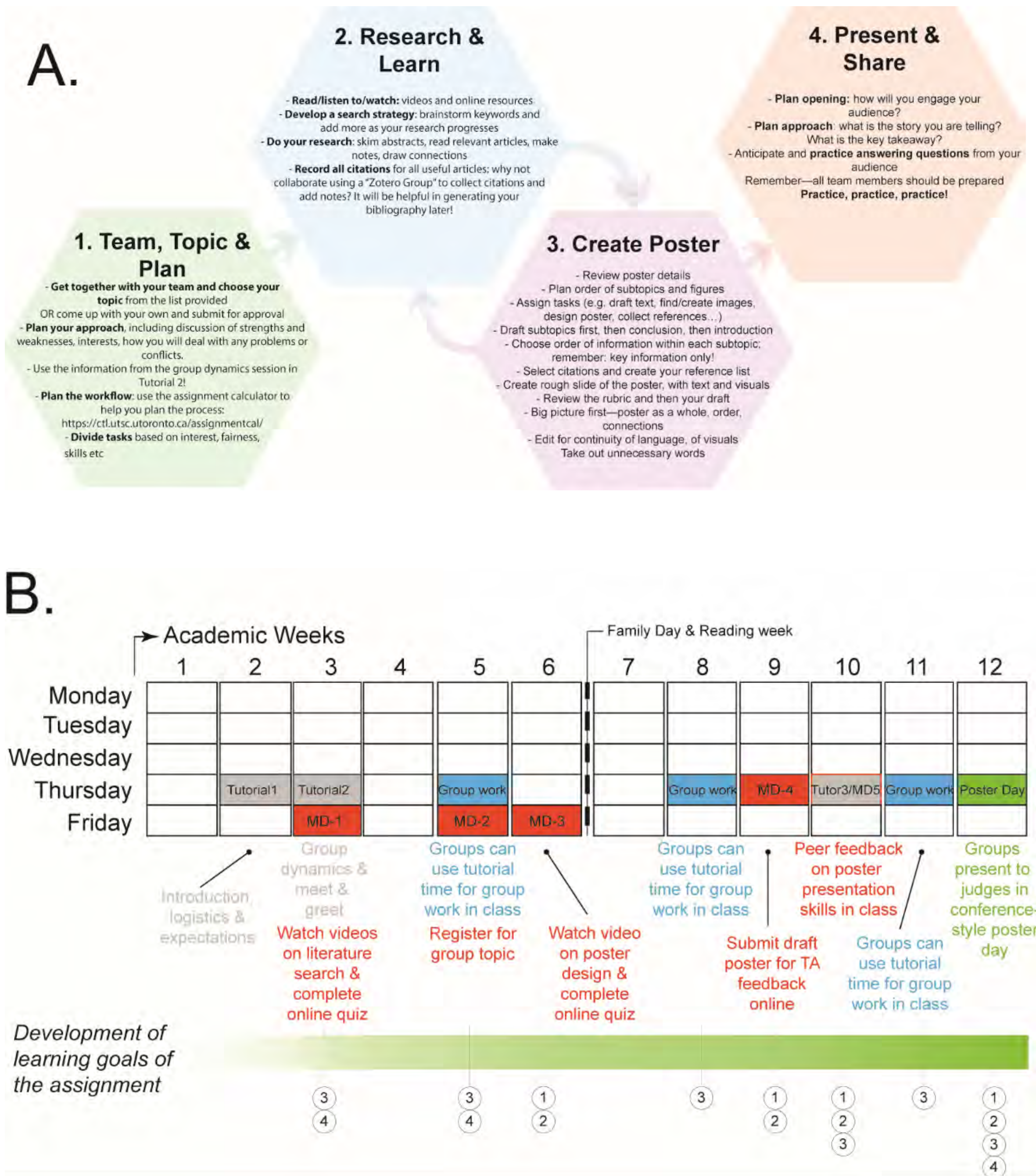


**Figure 1 – An overview of the design and expectations of the poster assignment.** A. This infographic provides an overview of the structure and expectations of the assignment. It provides students with a big picture summary of expectations, but also doubles as a guide or checklist throughout the semester. B. A timeline that summarizes the tutorials, group work sessions and deliverables (mini-deadlines, MD) of the assignment as implemented over the 12-week semester. Descriptions of the scaffolding tutorials, mini-deadlines and their links to the assignment's learning outcomes are provided below the timeline. Learning outcomes key: (1) = integration of knowledge, (2) = communication, (3) = teamwork, and (4) = information literacy.

both designated time and space for group discussions prior to important deadlines. This was intended to ameliorate the challenges that groups often face when they have to coordinate schedules and find available campus workspace in order to collaborate.

2 **Mini-deadlines**: The assignment required four deliverables over the semester prior to the final poster submission.

1. A quiz integrated into an online module on information literacy was available to students on our learning management system in week 3. This was intended to provide students with the necessary skills to search the literature for their project.
2. The second deliverable in week 5 was a group-based sign up for a specific research topic. We provided some topic choices and used the SignUpGenius platform for this mini-deadline (see Topic selection below).
3. In week 6, students were required to view an online video on creating research posters and then complete a quiz on the learning management system that tested their understanding of the basic parameters of effective poster design. We felt that this would equip students with a better understanding of the type of information that they should be seeking from the literature to create an effective poster.
4. The final mini-deadline in week 9 required students to submit final poster drafts. The assignment TAs and TAs of the participating courses provided formative feedback on the research posters (using the criteria in the evaluation rubric). On rare instances where groups reported a lack of contribution from specific members, the faculty and TA assigned social loafing penalties, as detailed in the teamwork section above. We ensured that TA feedback was provided to students by the end of week 10, such that there was still sufficient time to revise their work prior to the poster day in week 12.

3 **Topic selection**: We provided students with a list of topics with links to both primary literature and secondary sources for each topic. Students were nevertheless expected to conduct a survey of the primary scientific literature and make reference to at least six published papers in total, equally split across the sub-disciplines through which they would explore their chosen topic. Students were asked to explore a topic from at least two of the three possible perspectives represented by the three required courses in each term. Groups were provided significant free rein over topic selection and the instructors particularly emphasized their desire for students to go "off" the topic list provided; we were keen to ensure that students had a sense of ownership and autonomy right from the topic selection phase of the project. Students registered their topic and if choosing from the topic list provided, up to five groups could choose the same topic. We used the SignUpGenius platform (https://www.signupgenius.com/) for topic registration. Only two groups out of 130 chose topics from outside of our list.

4 **Assignment support:** The collaborative efforts of instructors, liaison librarians and Writing Centre staff in developing skills were intended to promote campus supports and resources often underutilized by students. Students were made aware that liaison librarians and Writing Centre staff were available for group consultations and feedback sessions respectively. A dedicated course site was established on our learning management system in order to provide resources for students. Students were supported by a project-specific TA, who coordinated all assignment-related logistics and took the lead in providing feedback on student work, organizing the final poster day and coordinating final grades. In addition, we had a few additional hours of TA support from TAs in each of the participating courses in order to provide formative feedback to students. A staff member managed all grades administration and provided general logistical support.

5 **Peer feedback session**: Studies that have incorporated peer-review and editing sessions in biology research projects have suggested that when students make keen observations to attempt to improve their peers' work, they often bring the same keen eye to their own work, resulting in an overall improved editing process (Carpenter & Pappenfus, 2009; Kolber, 2011). This served as one of the motivations to include an in-person peer feedback session in which groups took turns presenting their posters to two other groups. The students rated each other using the same grading rubric that would be used by judges in the final evaluation. While students could receive valuable feedback on the design, clarity, and effectiveness of their posters, we felt that this was also an opportunity for students to practice their oral presentation skills. We held this session in Week 10, two weeks prior to the final evaluation, as this would provide groups with sufficient time to edit and print their revised posters.

6 **Rubric development**: The rubric used for grading posters is provided in the Supporting Materials. In general, we aligned this rubric with our learning outcomes, thereby assessing knowledge integration, oral (and written) scientific communication, working as an effective group and information literacy. Given that this type of conference style presentation day (see point 7 below) requires a large number of judges, we created a very simplified grading system in which students could meet, fall below or exceed the expectations of the judges. Judges provided written

7 comments when students were below or above expectations. The grading rubric was designed in such a way that groups scoring 80% (i.e. 8/10) would be seen as meeting our expectations for solid integration of knowledge and evidence of effective communication, teamwork and information literacy skills. For each criterion where students were assessed as "above my expectation", 1% was added to the students' grade (i.e. added to 80%); while for each criterion where students were assessed as "below my expectation", an additional 1% was deducted from the students' grade. Therefore, students who exceed expectations for every criterion received 100%, and students who failed to meet expectations for every criterion received 60%. In the case where an evaluator felt that the poster deserved a grade lower than 60%, they would justify their decision in the comments along with the assigned grade. Each poster was judged at least twice and we generally see good consensus between the judges; however, we do not currently have means to ensure interrater reliability across the team of judges. A limitation of this approach is that some groups may suffer "harsher" judges than others.

8 **Final evaluation**: The assignment culminated in a poster day in which ~130 groups (composed of ~5-6 students) presented their work to judges drawn from graduate students, post-doctoral fellows, teaching technicians and faculty from the department. The poster day was held in a large event space equipped with ~35 poster boards similar to that used in academic conferences and included two, two-hour sessions of poster presentations (~65 posters per session). A total of ~40 judges participated in the poster day and each poster was judged 2-3 times.

**Outcomes:**

Studies suggest that skill development sessions improve students' critical thinking and ability to better understand the process of scientific inquiry (Chaplin & Hartung, 2012; Sato et al., 2014). While we did not overtly assess these potential outcomes, the majority of student posters presented claims from a variety of primary sources that were supported and critically evaluated. A distribution of grades from the pilot offering of the assignment is shown in Figure 2, indicating that majority of students met our learning goals. Unsolicited feedback from faculty and graduate student judges suggested that students were proud to present their research posters and actively engaged in discussion with regards to future work around their chosen topic, providing evidence that this assignment serves to engage students through its learner-centered design. (see note)

**Conclusions and Recommendations:**

We have presented our design of an integrative research poster assignment in biology intended to promote both transferable skill-development and growth towards budding biologists who are informed consumers of scientific literature. The performance of the majority of the students in this assignment is indicative of effective ability to both mine the scientific literature and to effectively communicate relevant information in both written and oral formats, by integrating ideas from different sub-fields of biology. This is similar to student reported gains in scientific communication skills when working on open-ended group research projects in related fields (Julien, Lexis, Schuijers, Samiric, & McDonald, 2012; Walton & Baker, 2009).

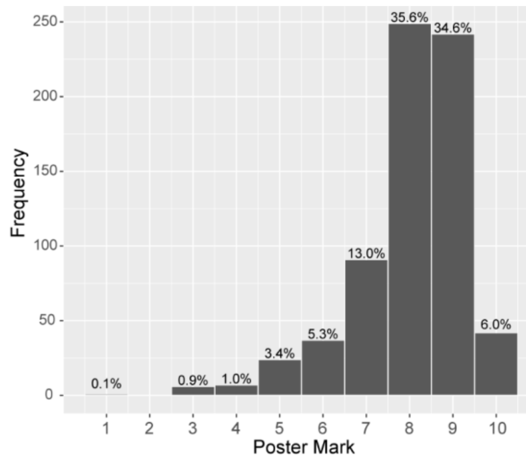


**Figure 2 – Student performance in the assignment**. The histogram shows the distribution of individual student grades in the assignment on a ten-point scale. Note that a score of 8 out of 10 was set as "meeting expectations" in our context and is detailed in the grading rubric (Supplementary Materials).

Some of the unique features of this assignment are that it is a required assignment for a large cohort of Biology program students registered in second year foundation courses and that collaborative work is encouraged among students enrolled across courses in biology. While other effective examples of integrative and interdisciplinary assignment approaches can be found in the literature, most report on smaller, upper-level courses, rather than large foundation ones (e.g. Jacques-Fricke, Hubert, & Miller, 2009; Liotta & Almeida, 2005). A linked course model developed at the University of Guelph is closely related to the design and rationale of our assignment (Husband et al., 2015). While their model offers further integration of courses through jointly mapped learning outcomes, small group seminars and other online content, our approach seeks to distil the integrative and skill development components into a single collaborative assignment. We believe that this pedagogy allows us to model scientific collaborations while promoting knowledge integration and building communication, teamwork and information literary skills.

This assignment could be used in its current form by biology instructors and could be easily adapted to other disciplines. To facilitate implementation of this assignment by other instructors, the syllabus style information document, grading rubric and sample topics are provided as part of the supporting information. Large student cohorts like ours can successfully work through this assignment format if TA support and some additional departmental and institutional resources (librarian support, large classrooms for group work, poster boards for the final presentation, faculty and graduate student time for poster judging etc.) are made available. We would recommend that a judges' briefing (or training) session be incorporated by others hoping to adopt this assignment and this is also one of our future objectives. In addition, instructors may consider using posthoc statistical corrections to correct for "harshness of judging" factors in the final evaluations. Investment in the resource requirements listed above could be considered negligible, given the significant anticipated learning gains for students. Indeed, this design of an assignment that transcends individual foundation courses could be seen as a means to not duplicate instructor time and resources in individual courses. Notably, this successful approach to assignment design, including contributions from liaison librarians, faculty and graduate students, advocates for collaboration in designing teaching and learning innovations in higher education.

Finally, we believe that this collaborative assignment mimics the goals of establishing learning communities (Andrade, 2007; Zhao & Kuh, 2004). In requiring students enrolled across courses to collaborate and interact beyond the classroom, we have created authentic opportunities for academic (knowledge integration) and transferable skill development within the social context of student teams. Several studies have suggested that students that participate in learning communities are more likely to embrace diversity, engage in peer-based learning environments and successfully complete their degree (Bean, 1988; Popiolek, Fine, & Eilman, 2013; Whitt, Edison, Pascarella, Terenzini, & Nora, 2001). In future years, it would be interesting to measure the impact of this assignment as a learning community on students' personal development and academic success.

**Acknowledgements:**

We thank Dr. Andrew Mason, Chair of the Department of Biological Sciences, for approving critical departmental supports including the assignment TA, rental of poster boards, additional admin support, and most importantly, for believing in the pedagogical value of this project. We thank all members of the department who enthusiastically supported student learning by coming out for several hours on poster day to serve as judges. We thank Adon Irani and Dina Soliman for their help in creating complex group structures across courses and for supporting this assignment's site on our learning management system. Finally, we thank the students enrolled in our second year core courses during the pilot year, who despite skepticism around mandatory group assignments, worked incredibly hard to meet our high expectations. In this manuscript, we are proud and grateful to be able to showcase the rewarding experience that these students have afforded us.

**References:**

Andrade, M. S. 2007. Learning communities: Examining positive outcomes. Journal of College Student Retention: Research, Theory & Practice. 9(1): 1–20. doi:10.2190/E132-5X73-681Q-K188

American Association for the Advancement of Science. 2011. Vision and change in undergraduate biology education: A call to action. Retrieved from https://live-visionandchange.pantheonsite.io/wp-content/uploads/2011/03/Revised-Vision-and-Change-Final-Report.pdf

Bean, J. P. 1988. Leaving college: Rethinking the causes and cures of student attrition. The Journal of Higher Education. 59(6): 708–711. doi:10.1080/00221546.1988.11780239

Bradforth, S. E., Miller, E. R., Dichtel, W. R., Leibovich, A. K., Feig, A. L., Martin, J. D., … Smith, T. L. 2015. University learning: Improve undergraduate science education. Nature News. 523(7560): 282. doi:10.1038/523282a

Cakir, M. 2008. Constructivist approaches to learning in science and their implications for science pedagogy: A literature review. International Journal of Environmental and Science Education. 3(4): 193–206.

Chaplin, S. B., & Hartung, N. Z. 2012. Integrative biology: A capstone course for an introductory biology core. Journal of College Science Teaching. 42(1): 31-39. Retrieved from https://www.nsta.org/college/

Crawford, J. C., Irving, C., Higgison, M., & Foreman, J. 2013. Information literacy and lifelong learning: Policy issues, the workplace, health and public libraries. Oxford, UK: Chandos Publishing.

Freeman, S., Theobald, R., Crowe, A. J., & Wenderoth, M. P. 2017. Likes attract: Students self-sort in a classroom by gender, demography, and academic characteristics. Active Learning in Higher Education. 18(2): 115–126. doi:10.1177/1469787417707614

Gibert, A., Tozer, W. C., & Westoby, M. 2017. Teamwork, soft skills, and research training. Trends in Ecology & Evolution. 32(2): 81–84. doi:10.1016/j.tree.2016.11.004

Gottschall, H., & Garcia-Bayonas, M. 2008. Student attitudes towards group work among undergraduates in business administration, education and mathematics. Educational Research Quarterly. 32(1): 3–29.

Government of Canada, Employment and Social Development Canada. 2017, March 2. Budget 2017 supports lifelong learning for a changing job market [News release]. Retrieved from https://www.canada.ca/en/employment-social-development/news/2017/03/budget_2017_supportslifelonglearningforachangingjobmarket.html

Husband, B. C., Bettger, W. J., Murrant, C. L., Kirby, K., Wright, P. A., Newmaster, S. G., … Wolf, P. 2015. Applying a linked-course model to foster inquiry and integration across large first- year courses. The Canadian Journal of Higher Education. 45(4): 244–260. Retrieved from https://eric.ed.gov/?id=EJ1086839

Jacques-Fricke, B. T., Hubert, A., & Miller, S. 2009. A versatile module to improve understanding of scientific literature through peer instruction. Journal of College Science Teaching. 39(2): 24–32. Retrieved from https://www.nsta.org/college/

Jensen, J. L., & Lawson, A. 2011. Effects of collaborative group composition and inquiry instruction on reasoning gains and achievement in undergraduate biology. CBE Life Sciences Education. 10(1): 64–73. doi:10.1187/cbe.10-07-0089

Julien, B. L., Lexis, L., Schuijers, J., Samiric, T., & McDonald, S. 2012. Using capstones to develop research skills and graduate capabilities: A case study from physiology. Journal of University Teaching and Learning Practice. 9(3): Retrieved from https://eric.ed.gov/?id=EJ996025

Kingsley, K., Galbraith, G. M., Herring, M., Stowers, E., Stewart, T., & Kingsley, K. V. 2011. Why not just Google it? An assessment of information literacy skills in a biomedical science curriculum. BMC Medical Education, 11, 17. doi:10.1186/1472-6920-11-17

Kingston, L. N., MacCartney, D., & Miller, A. 2014. Facilitating student engagement: Social responsibility and freshmen learning communities. Teaching & Learning Inquiry. 2(1): 63–80. doi:10.20343/teachlearninqu.2.1.63

Kolber, B. J. 2011. Extended problem-based learning improves scientific communication in senior biology students. Journal of College Science Teaching. 41(1): 32-39. Retrieved from https://www.nsta.org/college/

Kuh, G. D. 2003. What we're learning about student engagement from NSSE: Benchmarks for effective educational practices. Change: The Magazine of Higher Learning. 35(2): 24–32. doi:10.1080/00091380309604090

Liotta, L. J., & Almeida, C. A. 2005. Organic chemistry of the cell: An interdisciplinary approach to learning with a focus on reading, analyzing, and critiquing primary literature. Journal of Chemical Education. 82(12): 1794. doi:.1021/ed082p1794

Manske, S., Hecking, T., Hoppe, U., Chounta, I.-A., & Werneburg, S. 2015, June. Using differences to make a difference: A study in heterogeneity of learning groups. Presented at the 11th International Conference on Computer Supported Collaborative Learning (CSCL 2015), Gothenburg, Sweden. Retrieved from https://telearn.archives-ouvertes.fr/hal-01206688/document

Oakley, B. A., Hanna, D. M., Kuzmyn, Z., & Felder, R. M. 2007. Best practices involving teamwork in the classroom: Results from a survey of 6435 engineering student respondents. IEEE Transactions on Education. 50(3): 266–272. doi:10.1109/TE.2007.901982

Popiolek, G., Fine, R., & Eilman, V. 2013. Learning communities, academic performance, attrition, and retention: A four-year study. Community College Journal of Research and Practice. 37(11): 828–838. doi:10.1080/10668921003744926

Rateau, R. J., Kaufman, E. K., & Cletzer, D. A. 2015. Innovative classroom strategies that prepare college graduates for workplace success. Journal of Agricultural Education. 56(3): 52–68. doi: 10.5032/jae.2015.03052

Riebe, L., Girardi, A., & Whitsed, C. 2016. A systematic literature review of teamwork pedagogy in higher education. Small Group Research. 47(6): 619–664. doi:10.1177/1046496416665221

Roseth, C. J., Johnson, D. W., & Johnson, R. T. 2008. Promoting early adolescents' achievement and peer relationships: The effects of cooperative, competitive, and individualistic goal structures. Psychological Bulletin. 134(2): 223–246. doi:10.1037/0033-2909.134.2.223

Sato, B. K., Kadandale, P., He, W., Murata, P. M. N., Latif, Y., & Warschauer, M. 201). Practice makes pretty good: Assessment of primary literature reading abilities across multiple large-enrollment biology laboratory courses. Cell Biology Education. 13(4): 677–686. doi:10.1187/cbe.14-02-0025Stevens, C. R., & Campbell, P. J. 2008. Collaborating with librarians to develop lower division political science students' information literacy competencies. Journal of Political Science Education. 4(2): 225–252. doi:10.1080/15512160801998114

Strom, P. S., & Strom, R. D. 2011. Teamwork skills assessment for cooperative learning. Educational

Research and Evaluation. 17(4): 233–251. doi:10.1080/13803611.2011.620345

Tanner, K., Chatman, L. S., & Allen, D. 2003. Approaches to cell biology teaching: Cooperative learning in the science classroom—Beyond students working in groups. Cell Biology Education. 2(1): 1–5. doi:10.1187/cbe.03-03-0010

Walton, K. L. W., & Baker, J. C. 2009. Group projects as a method of promoting student scientific communication and collaboration in a public health microbiology course. Bioscene: Journal of College Biology Teaching. 35(2): 16–22.

Weimer, M. 2013. Learner-centered teaching: Five key changes to practice (2nd ed.). San Francisco, CA: Jossey-Bass.

Whitt, E. J., Edison, M. I., Pascarella, E. T., Terenzini, P. T., & Nora, A. 2001. Influences on students' openness to diversity and challenge in the second and third years of college. Journal of Higher Education. 72(2): 172–204.

Zhao, C.-M., & Kuh, G. D. 2004. Adding value: Learning communities and student engagement. Research in Higher Education. 45(2):115–138. doi:10.1023/B:RIHE.0000015692.88534.de