

Development of a Peer-Reviewed Open-Access Undergraduate Research Journal†

Evelyn Sun^{1‡}, Julia A. Huggins^{1‡}, Kirstin L. Brown^{2,3}, Rozlyn C.T. Boutin^{1,2,3},
William D. Ramey¹, Marcia L. Graves¹, and David C. Oliver^{1*}

¹Department of Microbiology and Immunology, University of British Columbia, Vancouver, BC V6T 1Z3, Canada;

²Canada's Michael Smith Genome Sciences Centre, BC Cancer Research, Vancouver, BC V5Z 4S6, Canada;

³Michael Smith Laboratories, University of British Columbia, Vancouver, BC V6T 1Z4, Canada

Dissemination of results is a fundamental aspect of the scientific process and requires an avenue for publication that is specifically designed to suit the nature of the research being communicated. Undergraduate research journals provide a unique forum for students to report scientific findings and ideas while learning about the complete scientific process. We have developed a peer-reviewed, open-access, international undergraduate research journal that is linked to a course-based undergraduate research experience. We reflect on lessons learned and recommend effective approaches for the implementation and operation of a successful undergraduate research journal.

INTRODUCTION

The well-documented benefits of undergraduate research experience on student development include increased research competencies, improved appreciation of the nature of science, and increased confidence and science identity (1–5). Research opportunities available to undergraduate students are quite diverse, ranging from mentorship-heavy internships to more self-directed research projects, often undertaken as a part of a course-based program. Regardless of the type of research experience or discipline, however, they all share a common, yet often underappreciated, component: the dissemination of findings to the broader community (6). Though findings can be communicated through poster or verbal presentations, the process of writing, reviewing, and revising undergraduate research findings yields unique learning benefits, including gaining authentic research experience, communicating using a standard disciplinary medium, sharing new knowledge with the community, and demonstrating research productivity (6, 7). Formal avenues for publishing undergraduate research allow students to gain the full benefits of this process (7).

*Corresponding author. Mailing address: 6270 University Blvd., Biological Sciences Building, University of British Columbia, Vancouver, BC V6T 1Z4, Canada. Phone: 604-827-2496. E-mail: david.oliver@ubc.ca.

Received: 5 May 2020, Accepted: 26 June 2020, Published: 31 August 2020

†Supplemental materials available at <http://asmscience.org/jmbe>

‡These authors contributed equally to this work.

Undergraduate research journals occupy a space uniquely positioned between traditional academic term papers (which are often written for the purpose of assessment with circulation restricted to the instructor and/or teaching assistants) and full-fledged professional research articles (which often take years of funding and work to complete).

While the benefits of undergraduate research experience are clear, the inherent limitations have led some to question the value and credibility of undergraduate research publications. Gilbert (2004) argued that (i) the inherent constraints of undergraduate research projects may lead to research articles that may not be ready for “prime time” (i.e., insufficient data worthy of publication), (ii) the incentive or requirement to publish in a journal adds pressure to students and faculty that may detract from educational learning goals, (iii) undergraduate students may have insufficient experience to effectively review research papers, and (iv) reporting results in an undergraduate research journal may not be recognized as a bona fide scholarly publication (8). Similarly, Aboshady and Gouda (2016) acknowledged the benefits of publication to undergraduate student development but noted that the quality of these publications may be weakened without rigorous peer review and searchable indexing methods (9). It is true that undergraduate research is typically conducted over an academic term or semester, with constraints on time, resources, and expertise affecting both the research and publication processes. There are, however, approaches to undergraduate publication that can nonetheless provide net benefits to both the students and the broader scientific community.

While a broad range of undergraduate research journals exist that vary in scope, focus, and operation, there is limited literature on how and why individual journals have been developed to meet the needs of students and the scientific community. Here we present a case study of a peer-reviewed undergraduate journal that is open to submissions from undergraduate students around the world. We discuss how the strategic implementation of specific measures, namely, introducing a peer-review process and establishing publication criteria, addresses some of the aforementioned caveats of undergraduate research journals (8, 9). We hope that sharing our experiences will produce a valuable resource to educators implementing and operating undergraduate research journals at academic institutions around the world.

UJEMI: a model undergraduate research journal

In 2001, the University of British Columbia (UBC) launched a capstone course-based undergraduate research experience (CURE) program in microbiology and immunology. The CURE takes place over the course of one academic term (i.e., 16 weeks), accommodating approximately 40 to 60 students working in teams of 3 or 4. The course is scaffolded on a series of structured writing assignments used to guide student teams through the research process. Following the steps of conventional scientific research, students first write a one-page letter of intent, which is refined over several weeks to yield a team-based research proposal. The students then engage in self-directed experimentation in the laboratory, working on their own schedules, with limited guidance from the instructor and teaching assistants. Finally, each team reports its findings in a scientific manuscript. At the end of the term, these manuscripts are reviewed by the course instructor and a graduate student teaching assistant, then returned to the student authors for revision.

Since the program's inception in 2001, the revised articles produced in these CURE courses have been archived in an open-access online undergraduate research journal titled the *Undergraduate Journal of Experimental Microbiology and Immunology* (UJEMI) (<https://ujemi.microbiology.ubc.ca/>). Formatting guidelines for UJEMI follow the Instructions to Authors from the *Journal of Bacteriology* (<https://jb.asm.org/>), which serve as a professional standard. UJEMI is a repository for new scientific findings, technical information about reagents and methods, and a growing body of literature derived from undergraduate research, which primes the feed-forward development of new research questions in subsequent semesters of the CURE. In essence, this unique format allows students to contribute to a collection of scientific knowledge built by their peers.

UJEMI papers are original research articles which follow the IMRAD (Introduction, Methods, Results, and Discussion) format. As part of the CURE, students learn about the structure and function of a research paper and are guided through the process of drafting a manuscript. By writing to the form of a disciplinary journal, students

learn to appreciate and understand the basic process of scholarly publication.

Given the constraints of undergraduate research, we found that adding a section within the Discussion describing "Study Limitations" was helpful to the students and the reviewers. The Study Limitations section is presented to student authors as an opportunity to leave a message for future researchers. For example, the authors may choose to explain why a certain control was used or why a limited number of experiments were performed. The students can also briefly elaborate on what additional experiments could be done in the future to support their findings or more rigorously test their hypotheses. This is the type of information that could potentially be gleaned from reading and rereading the paper, but in this case, authors are encouraged to be explicit, which in turn promotes scientific integrity. Writing a Study Limitations section also gives students the opportunity to explain intellectual follow-up "thought experiments" in the absence of the opportunity to conduct additional experiments in the laboratory.

The issue of retractions and errata has also been approached as an opportunity for students to learn about how science works. As a human endeavor, science incurs errors. Study limitations, misinterpretations of data, and experimental design weaknesses can lead to flawed papers. In many cases, the self-correcting nature of science through repeated experimentation resolves discrepancies as differences in experimental methodology. We have had course-based projects, however, where a result was clearly refuted. In these instances, we have directly amended the published paper to include a bolded statement within the abstract explaining the error. The erratum is linked directly to the paper that presents the data overturning a previous result. Although it is tempting to fully retract the paper reporting an erroneous result, we reasoned that this approach would detract from the learning experience by essentially altering the perception of how the project unfolded.

Peer review process

In the initial structure of the CURE curriculum and UJEMI publication, students were able to gain experience with many stages of the scientific process, including conducting literature reviews, identifying compelling research objectives, applying laboratory research methods, interpreting data, and preparing a manuscript for submission to a journal. From 2014 to 2019, we conducted an iterative review and revision of the UJEMI journal in order to update the publication process, giving students opportunities to experience additional aspects of the scientific process and addressing some of the previously mentioned limitations associated with undergraduate research journals. Specifically, to provide students with a more authentic and rigorous scientific communication experience, we introduced an optional formal peer review process and a second publication track, enabling students meeting established criteria

to publish their findings in the peer-reviewed version of UJEMI, called UJEMI+.

The overall manuscript review process involves two main stages, as shown in Fig. 1. Stage 1 involves editorial review by the course instructor and a graduate student teaching assistant, followed by the first round of revisions. This stage is required by all students as a part of the CURE. Stage 2, which is optional, is enacted after the academic term and involves double-blind peer review by two subject matter experts. Authors begin Stage 2 by completing a survey (Appendix 1) that asks them to concisely explain their research question, hypothesis, conclusions, supporting evidence, and study limitations. At the end of the survey, the students are asked whether they would like to submit their publication for peer review. This survey is designed to help the students assess the suitability of their research for peer review. Approximately two-thirds of the student teams who complete the survey decide to submit their papers for peer review. Expert peer reviewers are most often senior graduate students or postdoctoral fellows from UBC and other institutions around the world,

recommended by academic faculty for their expertise and perceived ability to effectively provide constructive feedback to undergraduate students. Standardized feedback forms (Appendix 2) are used to facilitate the peer review process and ensure a fair evaluation of all manuscripts.

While undergraduate research journals often engage undergraduate students as reviewers and editors, the UJEMI peer review process is administered by a graduate student who is employed as the Journal Editor for the 4-month summer term. Because the graduate student editors have more experience with formal scientific writing, they are able to both mentor the undergraduate authors and provide an objective perspective on the quality of the manuscripts, while facilitating the peer-review and publication processes. Furthermore, since the graduate student is formally employed, work expectations are more clearly defined and there is increased incentive for the student to take responsibility for the quality of the editorial process. At the end of the summer, UJEMI research articles are published as nonrefereed (UJEMI) or refereed (UJEMI+) undergraduate research articles. Importantly, papers published in the nonrefereed journal have a

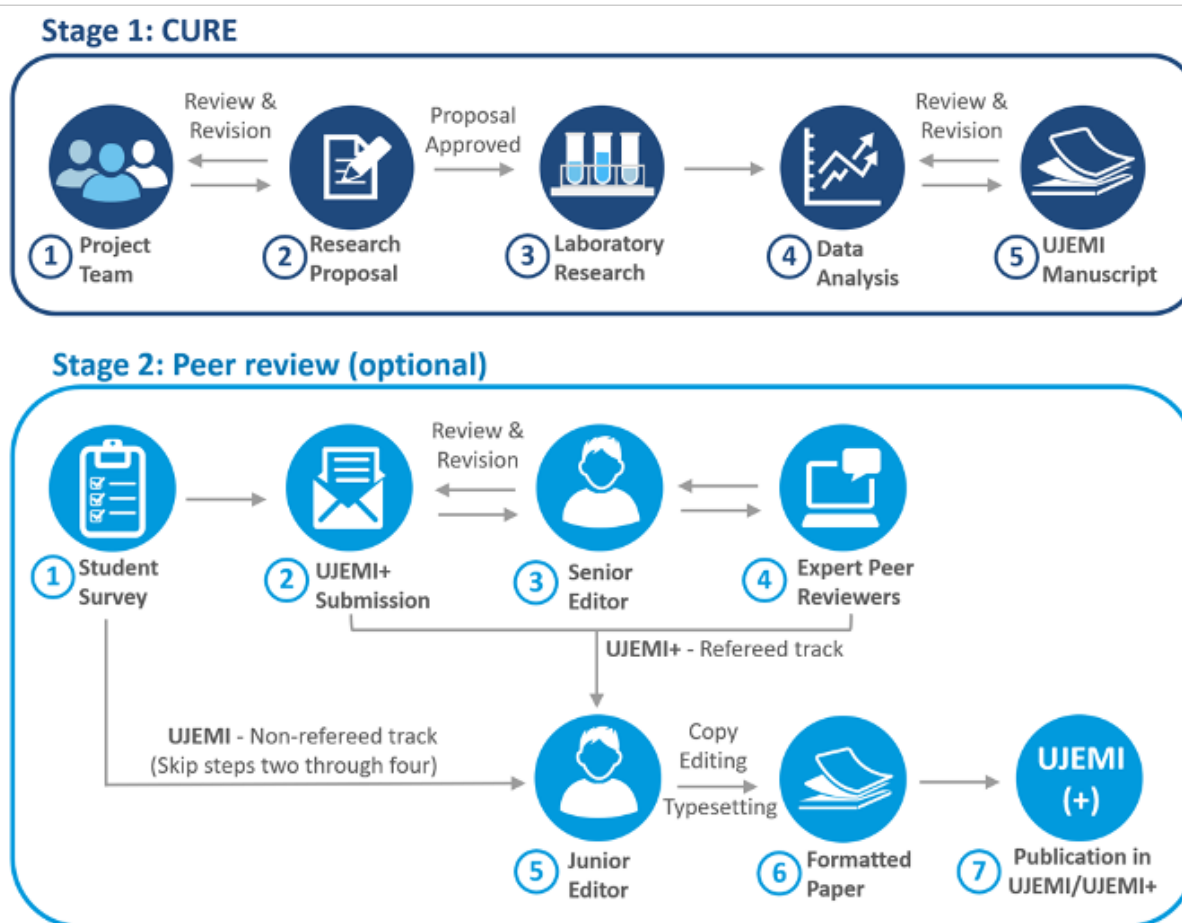


FIGURE 1. UJEMI two-stage publication process. Stage 1 follows the general process of completing a CURE-based project. Data generated from the project are summarized in a draft manuscript which undergoes review by the instructor and/or teaching assistant(s) before publication in UJEMI. Student teams have the option of going through Stage 2, which follows the peer-review process before being published in UJEMI+.

clear disclaimer printed on every manuscript stating that they are the result of undergraduate research and not peer reviewed. We believe that this transparency is fundamental for establishing a distinct role for undergraduate journals relative to other scientific publications.

Students in the CURE are encouraged to strive for a publication suited for peer review but are aware that their primary duty is to conduct well-controlled experiments and report their results with integrity. Making the peer review step optional is a unique feature of the model employed by UJEMI and mitigates academic pressure. Additionally, there is no penalty or bonus for publishing in the nonrefereed versus refereed versions of the journal. Most often, nonrefereed publications are work-in-progress communications which serve as valuable resources for student researchers in future CURE cohorts. Outright rejections are uncommon; the majority of papers can be revised and refined to meet publication standards. Tempering and refining conclusions that accurately reflect the data is the most common revision.

Similar to peer review for a professional research journal, the time invested by both the reviewers and the undergraduate authors results in more robust science communications. Importantly, this double-blind peer review step benefits not only undergraduate students by providing them with the invaluable learning opportunity to take part in the peer review process, but also provides an opportunity for graduate students and postdoctoral fellows to practice reviewing manuscripts. Overall, this process enhances the quality of their published work in professional journals and provides young professional scientists with undergraduate mentorship opportunities.

Operation and sustainability of UJEMI

An important factor in determining whether and how the full benefits of an undergraduate research journal are realized is the recruitment, training, and compensation of graduate student editors. We have recently deployed a model in which graduate student editors are compensated as part-time teaching assistants during the summer months. The editors manage the project by facilitating peer review (which includes identifying and reaching out to suitable referees), providing feedback to the student authors (which often involves interpreting the reviewer's comments), copyediting, and typesetting. The work requires project management, aptitude for teaching, attention to detail, and high-caliber writing skills in order to provide quality feedback. We have found that the most effective candidates for this position are graduate students who actively express an interest in high-quality scientific writing and developing their own teaching skills. Recruiting and selecting suitable editors is crucial, as the success of the peer review process rests largely within their purview. We are attempting to achieve year-over-year editorial consistency by hiring two editors on staggered-start 2-year terms where they focus primarily on copyediting and typesetting in year 1 (junior

editor) and facilitating peer review and mentoring the new editor in year 2 (senior editor) (Fig. 1). Best practices and templates for peer review, peer review questionnaires for student authors, and templates for typesetting are reviewed and updated annually.

The senior editor meets regularly with the junior editor to discuss peer-review progress and the status of submitted manuscripts. The junior editor also helps provide feedback to the authors of peer-reviewed manuscripts and contributes to publication decisions. Because the UJEMI+ publication process is structured as a guided learning experience, there are multiple opportunities for the junior editor to observe the senior editor's interactions with student authors and reviewers. After the junior editor has shadowed several interactions in the peer-review process, they are encouraged to take the lead in several stages of manuscript review. They then receive feedback from the senior editor and develop confidence to facilitate the full process the following year. Junior editors are encouraged to reflect on strengths and weaknesses of the process and implement improvements at the beginning of their second year, in conjunction with the annual review of the journal's best practices, e-mail templates, student questionnaires, typesetting formats, peer-review workflow, and publication policies. This approach to editor mentorship ensures the editors develop ownership in the journal's process and allows room for continuous improvement, while simultaneously promoting consistency and carryover of effective methods developed in previous years.

Our objective is to facilitate a learning experience for student authors, regardless of publication outcome. As such, it is key that editors and reviewers be prepared to provide feedback in a constructive manner that best promotes learning. Over several years of reflection and revision, UJEMI has developed a set of core methodologies that facilitate this. We use a structured review template that encourages constructive feedback, such as asking for information or ideas that may have been overlooked and soliciting alternative interpretations where reviewers disagree with students' conclusions. Though we do not specifically train or coach our reviewers (to ensure objectivity), we do introduce the specific aims of UJEMI+ when soliciting reviewers, and we request that principal investigators (PIs) recommend potential reviewers from their research groups who have an interest in undergraduate mentorship. Furthermore, we train our editors to approach the review process from a pedagogical perspective, with an emphasis on learning outcomes. Senior editors guide student authors throughout the process, including meeting to discuss the purpose of peer review before giving the reviews back to the students. In these meetings, students discuss the value of feedback and prepare to face criticism with a focus on improvement rather than defensiveness. Maintaining this approach is one of the main motivations for establishing a junior/senior editor training structure and focusing on institutionalized consistency within UJEMI.

The stability and longevity of UJEMI (established 2001) can be attributed to its linkage to a CURE. The CURE ensures that a dedicated faculty member has the time and resources required to develop and guide UJEMI operation in order to maintain quality and consistency. Student teams in our CURE contribute at least 20 to 25 papers per year, which yields a reliable source of content for the journal. The multitiered structure of UJEMI, which engages undergraduate students in the CURE, graduate students and postdoctoral fellows as reviewers and editors, faculty supervisors, and institutional administrative supports (e.g., CURE funding and pedagogical innovation grants), creates an adaptable community-based framework that supports and sustains the initiative.

Indexing, searching, and archiving UJEMI articles

Discussions around where and how UJEMI+ articles should be indexed are ongoing. At present, we currently use an in-house search function which is limited to research articles published in UJEMI. Google Scholar automatically “crawls the web” and adds UJEMI papers to its database; however, the time delay between online publication and appearance in Google Scholar can vary, meaning that UJEMI publications may not appear in literature searches when needed by students in subsequent terms of the course. More sophisticated search functions and linkages to scientific articles published in the broader literature would enhance the student experience. Whether UJEMI+ articles should be indexed within databases such as PubMed is open for debate. While the results of undergraduate research have merit and provide value to the scientific community, the papers are expectedly shorter than those published by full-scale grant-driven research labs. As such, the inclusion of UJEMI+ (and other peer-reviewed undergraduate research journals) in PubMed may add unnecessary complexity to the database. The idea of creating an indexed database devoted to undergraduate research articles that can link to larger databases (e.g., PubMed, Google Scholar) is compelling. This type of database would become a central hub for undergraduate research that extends into the broader community without cluttering up the space occupied by more extensive scientific articles published by conventional professional scientific journals.

As UJEMI and UJEMI+ publications accumulated and course-based projects developed, we realized that properly archiving the papers would be critical to the longevity and continued utility of the journal as a resource for other researchers. The journal website operates from a secure server; however, we have now initiated a project to store articles within our institutional library. Additionally, to facilitate online archiving and document retrieval, we apply a digital object identifier (DOI) to each paper. DOIs are identifiers that can be linked to metadata and web addresses for online archiving. Technological options such as cloud-based archival storage and DOIs, which are now readily

available and financially feasible to implement, ensure that online UJEMI articles will persist and can be easily located.

Inviting the world

We have been contacted by several students, educators, and institutions from outside of UBC inquiring about the possibility of publishing in UJEMI+, highlighting the important niche for undergraduate research journals in scientific education. The authors noted that UJEMI+ provided a useful and needed forum for publication of their research, prompting us to open UJEMI+ to submissions from undergraduate researchers around the world. Early submissions were received from smaller colleges around North America engaged in undergraduate research, and UJEMI+ has now published research from students internationally.

Manuscripts submitted from institutions outside of UBC are reviewed by the editor and, if suitable, are advanced to peer review. Externally submitted manuscripts are not required to be tied to a CURE experience but are subject to the same stringent peer-review process as UBC-based manuscripts. Experts from well-established research labs at UBC are often consulted to provide these external authors with support and feedback. In addition to providing a forum for members of the undergraduate research community to disseminate their findings, UBC students benefit from seeing their research presented alongside their peers from other institutions. This provides student authors with a sense of broader meaning and impact. It also establishes a standard of excellence as the work is now displayed on a world stage.

Authorship

With respect to the unique opportunity gap that we believe undergraduate journals should fill, authorship in UJEMI+ is restricted to undergraduate students enrolled at recognized postsecondary institutions. Student authors correspond directly with the journal editors to gain first-hand experience working through the peer-review process. UJEMI+ provides a guided publication experience that is more educational and supportive than that provided traditional scientific journals. Publication through full academic journals normally involves the PI or a senior scientist as the corresponding author, whereas publication through UJEMI+ involves direct correspondence with undergraduate student authors who, in turn, take part in revisions based on the editors' or peer reviewers' recommendations. It is key that UJEMI+ not be mistaken as a substitute publication pathway for PI-coauthored manuscripts that would be candidates for other professional scientific journals.

At the same time, UJEMI+ recognizes the importance of publishing high-quality scientific research conducted at accredited institutions; thus, to be considered for publication in UJEMI+, we require a formal endorsement from a course instructor or researcher who mentored the student authors. Published manuscripts include a section explicitly acknowl-

edging this endorsement. This helps verify the authenticity of the primary research and ensures mentors are recognized for their effort, which may be important for their own advancement in academia. Through this unique combination of requirements, namely, exclusive undergraduate authorship with a formal mentor endorsement, UJEMI+ fills the intended niche by publishing credible research without competing with professional journals.

DISCUSSION

The UJEMI model is constantly being updated to leverage new technology and approaches that best support the dissemination of scientific knowledge. Some of the tips presented here have been adapted from practices employed by professional scientific journals to meet the specific needs of an undergraduate research journal, while others are somewhat unique to UJEMI (e.g., study limitations) and possibly provide more transparency than some professional journals.

Previous reviews have highlighted valid concerns limiting the effectiveness and utility of undergraduate journals (8, 9), which must be taken seriously when considering

venues for undergraduate publication. Simply introducing a peer-review process does not alleviate all concerns, but with strategic implementation of specific methods, many previously mentioned issues can be addressed. We have developed and implemented a program that addresses many of the concerns commonly raised regarding undergraduate research journals, as summarized in Fig. 2.

UJEMI engages undergraduate students, graduate students, postdoctoral fellows, and faculty mentors with a specific focus on studies related to the fields of microbiology and immunology. The cross-cutting organizational structure involving mentor-mentee interactions between trainees at various levels and its disciplinary concentration are defining features of the UJEMI model. Within the landscape of undergraduate research journals that publish life sciences research, the majority are run by undergraduate students either exclusively or with a faculty supervisor. UJEMI, on the other hand, operates with faculty supervision and graduate student editors. Most undergraduate journals publish open-access online articles; few are indexed but the majority are peer-reviewed to some extent. The peer-review process for most undergraduate journals is not explicitly outlined or published. Here we present the UJEMI model of peer review which, unlike traditional routes, takes on a

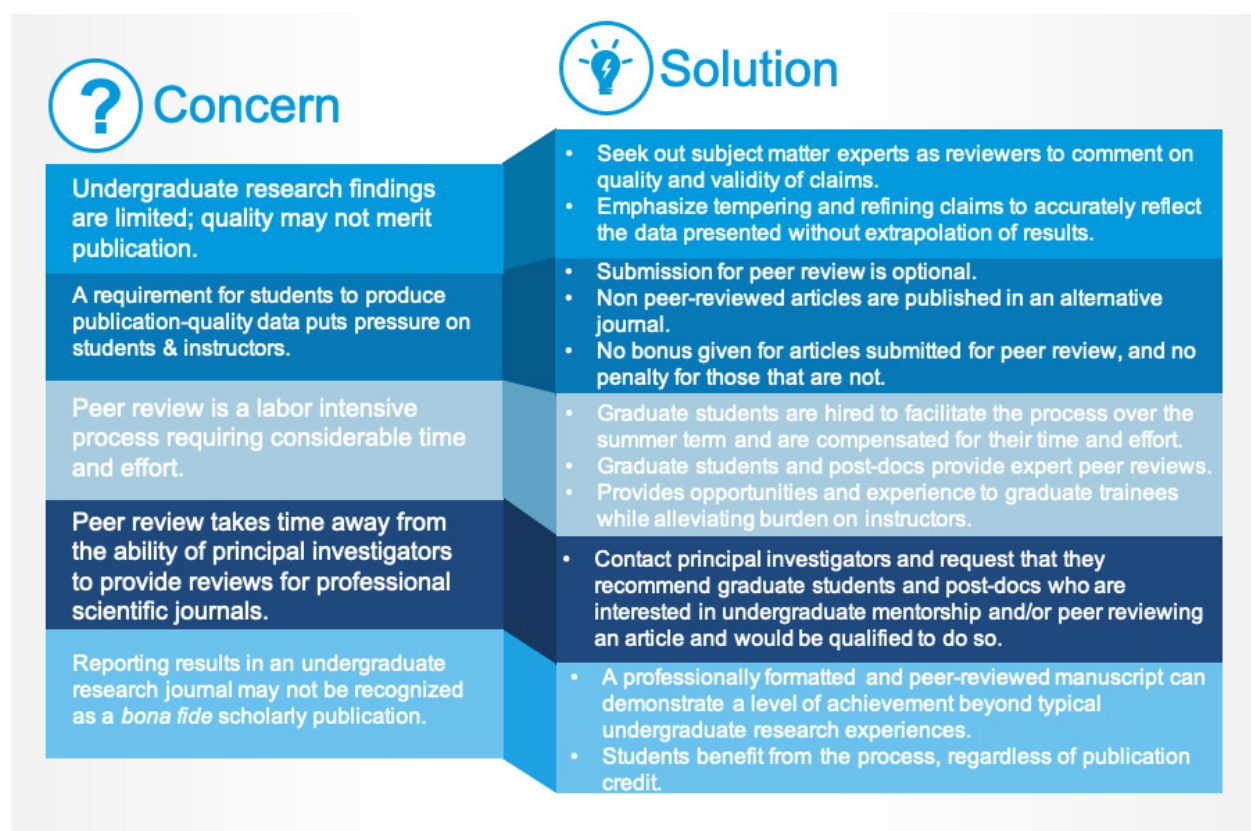


FIGURE 2. Caveats concerning undergraduate research journals and how UJEMI addresses them. General concerns surrounding the implementation of undergraduate journals are summarized from literature (8, 9). Solutions presented reflect approaches developed for UJEMI+.

more pedagogical approach to cater to its target authors. Comparable undergraduate research journals include the microbiology-based *FineFocus* (<https://www.finefocus.org/>), which is run by undergraduate students at Ball State University as an immersive learning experience. Other journals, such as the *American Journal of Undergraduate Research* (<http://www.ajuronline.org/>) and the *Canadian Journal of Undergraduate Research* (<https://cjur.ca/>), have a more general focus (i.e., publish papers from a broad range of disciplines) and utilize faculty-based and undergraduate student-based editorial teams, respectively. Different models for operating undergraduate research journals are expected to define the learning outcomes for participating individuals.

Some of the challenges associated with implementing and operating an undergraduate research journal like UJEMI are shared with professional journals. The capacity of UJEMI to carefully review and publish articles at scale is bottlenecked by the funding needed to compensate graduate student editors for their time. Efficiencies such as the recent implementation of a web-based journal management system (e.g., <https://openjournalssystem.com/>) through our institutional library has markedly helped manage the gathering of metadata for archiving and indexing as well as workflow (e.g., corresponding e-mails between the editor, authors, and reviewers) during peer review. We have also initiated a project to generate videos outlining the UJEMI production process that will be used to train future editors as a form of institutional memory.

CONCLUSION

To conclude, we have found that an undergraduate research journal can be used effectively and responsibly as both a pedagogical tool and a portal for disseminating authentic research. We suggest that the purpose of an undergraduate journal is not to create a product that competes with the so-called professional journals, but rather one that represents an opportunity to provide students with a unique platform to disseminate their research findings and contribute to the scientific body of knowledge. Dissemination of research through publication is a crucial aspect of the scientific process that should be taught and practiced at an undergraduate level as a means to introduce students to the complete, authentic research process (10). Based on our experience developing an international open-access peer-reviewed version of UJEMI linked to a CURE, we feel that the arguments against undergraduate research journals can be reasonably addressed in order to create an authentic learning opportunity that allows undergraduate students to contribute in a meaningful way to their scholarly communities.

SUPPLEMENTAL MATERIALS

- Appendix 1: E-mail and survey to invite to participate in peer-review process
- Appendix 2: Standardized review form used by peer reviewers during stage 2 of the UJEMI publication process

ACKNOWLEDGMENTS

We thank Michael Gold for his encouragement, guidance, and support during the development of UJEMI+. All authors participated in the preparation of the manuscript. Funding for the work presented in the manuscript was provided by the University of British Columbia's Department of Microbiology and Immunology, UBC Skylight Science Centre for Teaching and Learning, and a grant awarded by UBC's Program for Undergraduate Research Experience to D.O. and M.G. The authors have no conflicts of interest to declare.

REFERENCES

1. Hernandez PR, Woodcock A, Estrada M, Schultz PW. 2018. Undergraduate research experiences broaden diversity in the scientific workforce. *BioScience* 68:204–211.
2. Laursen S, Hunter A-B, Seymour E, Thiry H, Melton G. 2010. Undergraduate research in the sciences: engaging students in real science. John Wiley & Sons.
3. Lopatto D. 2007. Undergraduate research experiences support science career decisions and active learning. *CBE Life Sci Educ* 6:297–306.
4. Eagan K, Hurtado S, Chang MJ, Garcia GA, Herrera FA, Garibay JC. 2013. Making a difference in science education: the impact of undergraduate research programs. *Am Educ Res J* 50:683–713.
5. Russell SH, Hancock MP, McCullough J. 2007. Benefits of undergraduate research experiences. *Science* 316:548–549.
6. Marken L, Dawson D. 2017. Undergraduate research journals: benefits and good practices of involving students in content creation and other scholarly communication activities. WILU 2017 Conference, University of Alberta, May 2017.
7. Jungck JR, Harris M, Mercuri R, Tusin J. 2004. Points of view: should students be encouraged to publish their research in student-run publications? *Cell Biol Educ* 3:24–26.
8. Gilbert SF. 2004. Points of view: should students be encouraged to publish their research in student-run publications? *Cell Biol Educ* 3:22–23.
9. Aboshady OA, Gouda MA. 2016. Pros and cons of student journals. *Perspect Med Educ* 5:63–64.
10. Siegel V. 2004. Points of view: should students be encouraged to publish their research in student-run publications? *Cell Biol Educ* 3:26–27.