Facilitating Scientific Literacy Through Writing: A Write-to-Learn Assignment for Large Introductory Undergraduate Biology Courses

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Abstract

Write-to-learn (WTL) assignments have been used in a variety of disciplines to encourage conceptual learning and critical thinking in undergraduate education. These assignments focus on facilitating rather than assessing learning. Conversely, write-to-communicate (WTC) assignments (e.g., lab reports and exams), often with the goal of assessing learning, are more commonly employed in foundation STEM courses. We developed a WTL assignment that focuses on promoting curiosity driven learning, critical thinking, and metacognition; skills that promote students’ scientific literacy through writing. We integrated theoretical frameworks for scientific literacy, that include the sub-constructs of third space, authenticity, and multiple discourse as well as science as a human endeavour, and metacognition and self-direction (1, 2) to develop this 3-part WTL assignment. In this assignment, students first select a topic of interest and write freely on their current understanding of the topic (Part 1). They then develop a research question based on their writing and seek answers to their question from published literature (Part 2). Finally, they reflect on their overall experience with the WTL process and propose further avenues of investigation for their research topic (Part 3). Student feedback suggests that they enjoyed the WTL process and their overall satisfaction with the structure of the assignment was high. As we continue to evolve the assignment based on student feedback, we are gratified that students reported high self-efficacy with regard to future writing as a result of participating in this assignment. We recommend use of this type of WTL assignment in large, introductory STEM courses, so as to facilitate rather than simply assess students’ learning.

INTRODUCTION

“The first draft is just you telling yourself the story.”
— Terry Pratchett, author

Writing assignments have been extensively used in a wide range of higher education settings to both assess and facilitate learning (3, 4). Write-to-Learn (WTL) assignments are designed to facilitate conceptual learning and critical thinking through the process of curiosity motivated writing (5, 6). Some examples of WTL assignments include free-writing (writing freely on a topic only using one’s current understanding), scenario-based writing (problem solving within the context of proposed hypothetical scenarios), and journaling (beginning with free-writing and creating more formal texts through the process of drafting and revisions) (6, 7). It has previously been shown that WTL assignments have been correlated with a deeper understanding of course material, and long-term retention of concepts when assessed by student perception surveys and post-course retention tests (7, 8). Studies have also compared student writing following extensive engagement with a WTL assignment to writing from students that have not engaged with a WTL assignment. These investigations conclude that WTL assignments improve students’ ability to explain concepts and develop argumentation (7, 9, 10). WTL assignments are not routinely used in introductory foundational biology courses (3, 11, 12) because write-to-communicate (WTC) assignments (i.e., lab reports, exams, presentations) tend to predominate. WTC assignments often have the goal of assessing rather than explicitly facilitating understanding (13, 14).

WTL assignments that engage cognitive and metacognitive processes are correlated with better academic performance as assessed by final tests and assignment analysis (4, 15, 16). Additionally, positive activity-related emotions (i.e., ‘enjoyment’) as well as curiosity-driven learning are correlated with improved academic performance and retention (17–20). Inspired by published evidence, we highlight below a broadly applicable WTL assignment framework designed to promote curiosity-driven learning, scientific literacy, and metacognition in two introductory (1st year) biology courses at the post-secondary level.

Students enrolled in two, 12-week-semester-long first year biology courses (BIOA01H and BIOA02H) at the University of Toronto, Scarborough, were asked to complete a WTL assignment in both the fall (BIOA01H) and winter (BIOA02H) semesters. Both courses were intended for science majors and included three modules of biology sub-disciplines

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taught at an introductory level. Students selected a topic of interest from these sub-disciplines to complete their WTL assignments (Supporting File S1). The assignment spanned 11 weeks and accounted for 6% of students' final grade in each course. Instructors evaluated learning based on students' ability to meet or exceed the assignment expectations, which includes consistent improvement in writing over the course of the assignment. Assignment guides and rubrics were made available to students at the beginning of each semester (Supporting File S2).

We reference two theoretical frameworks in our assignment design. Wallace's theoretical framework for scientific literacy proposes three sub-constructs: third space (connecting personal to academic understanding), authenticity (motivation to engage in scientific discourse), and multiple discourse (confidence to shift from a private to authoritative tone in discourse) (1, 14). Choi et al. propose a theoretical framework that follows 5 dimensions: content knowledge (understanding of scientific concepts that explain the world around us), habits of mind (layers scientific inquiry, communication, and problem solving), character and values (attitude and motivations behind learning science), science as a human endeavour (contextualizing science in social and life contexts), and metacognition and self-direction (self-awareness of one's own thinking processes) (2). Wallace's framework is ideal in our goal to scaffold the development of first year students from novice learners to confident, accurate consumers of scientific literature. From Choi et al.'s framework, we draw on the concepts of science as a human endeavour and metacognition and self-regulation to guide our assignment design (2). These two sub-constructs supplement Wallace's framework by way of considering diverse personal and social contexts, and personal reflection in the learning process.

The writing assignment encompassed three parts: 1. Free-Write, 2. Explore and Research, and 3. Reflection. These parts were designed to encourage curiosity-driven writing and research, critical thinking, and metacognition. We share our assignment design (Supporting File S3) and provide the rationale and expectations that frame each of the three deliverables below.

PART 1: FREE-WRITE

Rationale

Part 1 of the assignment asked students to select a topic of interest and write what they already knew about it through previous knowledge or experience without considering scientific accuracy. This process is known as the WTL strategy of free-writing (14). Aligning with the sub-constructs of authenticity (1) and science as a human endeavour (2), Part 1 fosters intrinsic curiosity, enthusiasm, and motivation. Specifically, free-writing allowed students to connect their personal understanding to course related topics and urged them to be curious and motivated to explore a topic further by formulating a research question.

Structure

A broad range of 50–70 topics listed were available for student reference, organized by course modules (~16–23 topics per module) (Supporting File S1), ensuring that the selection process reflected students' interests and curiosity. Students could also select topics outside of the provided list following approval by the course instructor. By having students write freely on a topic of their own interest, we invite all students, from diverse backgrounds and with diverse abilities with respect to writing, to engage with their learning using writing as a medium. Students are then able to build on their unique initial understanding of a topic as they complete the subsequent sections of the assignment.

Students were asked to write half a page (125–150 words) about their topic using their current knowledge and understanding, without conducting any research. This did not require students to be familiar with their chosen topic. The goal was to candidly relay students' current knowledge on a topic that they were curious about and identify gaps in their understanding. Finally, students were asked to identify 1–2 preliminary questions they may have about this topic, creating the foundation for inquiry and research in subsequent stages of the assignment.

Students were given three weeks (end of Week 3) to complete Part 1, and were able to reach out to the course coordinator, instructors, and teaching assistant (TA) for questions throughout the semester. Designated WTL assignment TA office hours were available weekly throughout the semester. Additionally, writing and academic English support was available to students through our institutional Center for Teaching and Learning in the form of workshops, tutoring, and writing-specific office hours.

PART 2: EXPLORE AND RESEARCH

Rationale

Part 2 of the assignment focused on facilitating research driven writing. Students engaged in cognitive processes such as elaboration and explanation to connect personal knowledge to a more thorough understanding of the topic by reading scientific literature. This aligns with the theoretical sub-constructs of third-space (1) and science as a human endeavour (2). Using the research question posed in Part 1 of the assignment, students were able to perform targeted literature review to align their own understanding to academic understandings of their topic. Students were encouraged to discuss if and how scientific literature was able to answer their questions and inform their understanding of the topic.

Structure

Students were asked to select one primary peer-reviewed journal article that best related to the questions posed in Part 1. Students were provided with library resources on effective literature searches and were asked to write a one paragraph original summary of their selected article (Supporting File S4). The summary was required to include the following information: (i) what did the article study? (ii) how did they study this (i.e., methodology)? (iii) what were the results of the study? and (iv) what were the salient conclusions? Students were also asked to include accurate in-text citations and a mini bibliography with their summary. Finally, students were asked to pose 1–2 new questions based on their reading and research that follow from their original questions in Part 1. Students were given four weeks (end of Week 7) to complete Part 2.
PART 3: REFLECTION

Rationale
Part 3 asked students to reflect on what they had learned as well as to connect ideas from the first two parts of the assignment with new knowledge. This section engages with the theoretical sub-construct of multiple discourse (1), as it further develops students’ authoritative engagement with the discourse around their topic. Students also engaged in metacognitive techniques, such as association, and reflection. Aligning with the metacognition and self-direction sub-construct from Choi et al. (2), these techniques allow students to become active in their learning and solidify their understanding around a particular topic; parameters correlated with academic success (21, 22).

Structure
Students were asked to select another peer-reviewed article to further develop their understanding of their topic of interest and make connections from the article to the questions they posed in Parts 1 and 2. Students were expected to include proper citations and references in The Council of Science Editors (CSE) format. Next, students were asked to write a reflection on their research process, addressing how their research questions and misconceptions were clarified over the course of the assignment. Finally, students were asked to discuss future directions for their research.

Students were given four weeks (end of Week 11) to complete Part 3. The final writing assignment submission was three pages in length (not including references), with headings to separate the various parts of the assignment.

We note that the WTL assignment differed slightly between BIOA01H (fall course) and BIOA02H (winter course), as we accounted for student submission trends and potential misconceptions. In BIOA01H students were asked to work systematically through the 3-part paper and then submit the entire assignment at the end of Week 11. We noticed that there was a small proportion of students engaging with the feedback process in this format. We also noted that there was no scaffolding in place to prevent students completing the assignment in an altered order (e.g., rushing to complete Part 2 before really engaging with Part 1). Hence, in BIOA02H (winter course), we asked students to submit three distinct deliverables on a 3–4 week timeline for each. Feedback on submitted parts were available to students prior to the submission deadline of the subsequent section, allowing the feedback process to be better integrated into the structure of the assignment. The results and conclusions highlighted in this paper represent survey responses from both A01 and A02 student experiences.

TEACHING ASSISTANT FEEDBACK

Rationale and Structure
Feedback has been shown to enhance student understanding of content, content retention, and learning experience (23). Implementation of TA feedback differed slightly between BIOA01H and BIOA02H. In BIOA01H, students were able to submit a first draft of the collective 3-part assignment to the TA for feedback through the online course portal. Students were then able to make edits based on TA comments before submitting a final version for grading. However, we noticed that only 1/3rd of students chose to engage in this optional feedback process. Therefore, in BIOA02H, TA feedback was offered in the form of written comments and designated online office hours and workshops. The assignment was submitted as three separate deliverables corresponding to each of the three parts. Students received written feedback on their submitted work prior to the submission deadline of the following assignment section. We offered a total of 11 office hour/workshop sessions over the course of the semester and an average of 26 students attended each session. We encouraged students to utilize the feedback process in both courses. However, given that this was not a mandatory component of the assignment, we acknowledge that student experience was likely heterogeneous.

STUDENT PERCEPTION AND RESULTS

A short, anonymous, online survey was administered to students to understand their experience and feedback on this assignment. This survey was distributed at the end of week 12 in each term and remained available to students for eight days. We obtained a response rate of 16% (n = 136) and 87% (n = 858) for the fall and winter semesters, respectively. We provide a summary of the 990 total student responses and our findings below.

Gratifyingly, the majority of survey respondents agree that the instructions and information provided on our online learning management platform (Quercus) (86.77%) and from the TA (79.52%) adequately prepared them to complete the assignment (Figure 1A). The majority of survey respondents (71.33%) found TA feedback helpful in improving their writing (Figure 1B). In analysing student feedback (Figure 1C), 20.40% of responses suggested that the WTL assignment did not need any improvements, while others made several types of suggestions for improvement. Of those, the largest category of responses (19.70%), indicated that allowing a higher word count or page limit would have improved the assignment overall. Other suggestions included, allowing rough draft submissions and feedback (6.18%), a more descriptive rubric (5.83%), and enabling an option to complete other parts of the assignment despite missing a previous one (2.68%) (Figure 1C). In the interest of a student experience informed approach and to provide flexibility and inclusion in the curriculum, modifications in line with these suggestions will follow in future iterations. Taken together, this suggests that students had an overall positive perception of this initial assignment design and provided thoughtful suggestions for the evolution of our design.

Students also indicated that they found at least one or more aspects of the assignment enjoyable (Figure 2). The majority of students found Part 2 (56.06%) and Part 1 (22.14%) of the WTL assignment most enjoyable, while Part 3 was not reported as enjoyable (0.47%). We note that 1.63% of students suggested removing Part 3 as they felt it was repetitive (Figure 1C). One contributing factor may be that students were not provided clear instructions on how to formulate and write a reflection. Therefore, it might be beneficial to incorporate such instruction in future iterations.
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Figure 1. Assignment design and TA feedback are favourably reviewed by students. (A) When asked whether BIOA02 students (n = 854) felt that the assignment instructions posted on the online learning management system, Quercus, adequately prepared them to complete the WTL assignment, the majority either strongly agreed or somewhat agreed. Additionally, when asked whether information provided by the TA was helpful in completing the WTL assignment, the majority of students either somewhat agreed or strongly agreed. (B) Of 136 BIOA01 student responses, the majority of students either somewhat agreed or strongly agreed that feedback provided by the TA on the WTL was helpful in improving their writing. (C) When BIOA02 students (n = 858) were asked how the WTL assignment could be improved, the top three responses were that the WTL assignment was not in need of any improvements (red), allow for a higher word count/page limit (orange), or submit the entire assignment at once (yellow). A smaller proportion of students suggested other improvements (Other; brown) such as, providing a broader list of topics (5.83%), including additional help/workshops (2.68%), having no limits on the publishing date of the articles selected (0.47%), being more lenient on formulating questions (0.35%), and not including the assignment in the syllabus at all (0.35%). 3.85% of respondents could not provide an answer to this question.

Figure 2. Students rate Explore and Research (Part 2) as the most enjoyable aspect of the WTL assignment. Of 838 student responses, the majority of BIOA02 students (93.12%) found at least one aspect of the WTL assignment enjoyable. The three most enjoyable aspects of the WTL assignment are Part 2 (Explore and Research) (red), Part 1 (Free-Write) (Orange), and that the assignment was composed of Three Manageable Parts (yellow). A smaller proportion of students (Other; brown), indicated that constructive feedback (0.82%), and Part 3 (Reflect) (0.47%) were the most enjoyable aspect of the assignment. 4.31% of respondents could not comment or did not provide a response to this survey question.
Students’ overall positive attitude towards the WTL assignment is encouraging, as it has been shown that positive activity-related perceptions correlate with academic success (17), and can positively impact students’ self-regulated learning (17–20, 24). Gratifyingly, this aligns with students’ feedback, as students reported high self-efficacy with regard to writing as a result of participating in this assignment (Figure 3). This opinion was consistent between the BIOA01H (87.10%) and BIOA02H (79.64%) student populations.

Overall, we conclude that student satisfaction with this WTL assignment structure was high. We acknowledge that our assignment design can be improved based on student input and feedback (Figure 1C). For example, we hope to incorporate more specific instructions around writing reflections and develop a research “how-to” resource page to support student learning in this assignment. Moving forward we hope to include pre- and post-tests to assess science literacy and conceptual understanding. We also hope to correlate student WTL assignment grades with in-course test grades to understand the specific effect of this WTL assignment on learning and retention of foundational biology concepts. Based on student survey feedback, we find that this WTL assignment was both beneficial and well received by students. We hope it will be of significant interest to other STEM educators as a means to facilitate learning in foundation courses.

SUPPORTING MATERIALS

- S1. Write-to-learn biology – Example Topics
- S2. Write-to-learn biology – Grading Rubric
- S3. Write-to-learn biology – Sample Assignment Guide
- S4. Write-to-learn biology – Library Resources

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Please note that the survey responses included in this manuscript represent secondary research use of anonymous information as defined by the federal research ethics guidelines in Canada. Ethical conduct for research involving humans, 2nd Edition (TCPS-2), Article 2.4 states, regarding secondary use of anonymous information: “REB review is not required for research that relies exclusively on secondary use of anonymous information.”

REFERENCES


