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| Tips and Tools

Boosting student performance with inclusive writing-to-learn assignments through graphic organizers in large enrollment undergraduate biology courses

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ABSTRACT Logistical challenges in large enrollment classes are often mentioned as obstacles to active learning. Writing is an integral part of being a scientist and is often one of the first tools considered by STEM instructors to increase student engagement, but iterative writing assignments in large classes require creativity on the part of the instructor. We found an association between writing-to-learn assignments designed to be consistent with inclusive learning pedagogies and student performance measures in a large enrollment undergraduate biology course. They provide ample opportunity for deliberate practice and inclusive engagement, components of the "heads and hearts" hypothesis posed to explain the variation in active learning impacts on the performance of minoritized students.

KEYWORDS writing-to-learn, inclusive pedagogies, active learning

A meta-analysis of 200+ studies indicated increased undergraduate student performance in active learning STEM environments over didactic instructional settings (1). Most definitions of active learning in biology education lie within a constructivist theory framework (2). Active learning has been shown to narrow STEM achievement gaps in minoritized populations (3, 4). Active learning and inclusive pedagogies, while related, are not the same. Inclusive pedagogies require (i) student-teacher-environment contexts to be considered before choosing active learning tools (5), (ii) deliberately implementing tools to facilitate scaffolding, feedback, and repetition, and (iii) treating students with respect and capable of intellectual and personal growth, components of the "heads-and-hearts" approach (3).

Despite the promise of active and inclusive learning, a study of 2,000+ undergraduate STEM classes indicated a majority (55%) were didactic, and only 18% were student-centered (6). Logistical challenges in large enrollment classes are viewed as obstacles to active learning (7, 8). Writing is integral to being a scientist and is considered by STEM instructors to increase student engagement, but iterative writing assignments in large classes require instructor creativity (9). We accepted this challenge by investigating the effectiveness of writing-to-learn (WTL) interventions in a large enrollment cell biology class. The WTL treatment was associated with higher assignment scores than the writing-to-communicate (WTC) treatment (4, 10). While WTC tasks consider the audience, the WTL audience is the writer. We used resources available for large classes at doctoral-granting institutions including a team of instructors, graduate students, teaching/learning assistants, and online peer evaluation and assessment. We implemented similar WTL interventions in an introductory biology class at a primarily undergraduate institution with a smaller supporting cast and less technological tools. Our WTL assignments were designed to engage students in the process of scientific literacy development (10) and were consistent with inclusive learning pedagogies (11).

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PROCEDURE

An outline of a cancer biology example of WTL modules is detailed in reference (9). These WTL modules contain basic components, involve an instructional team, and incorporate inclusive learning pedagogies (Table 1). For WTL tasks, students had the option of using graphic organizers (GO), tools that show relationships among concepts (Table 1). GOs include concept maps, Venn diagrams, tables, and story maps (12).

A challenge to incorporating WTL into large classes is choreographing the logistics of the components. A detailed calendar for the instructional team and students is essential (see supplemental material). The most rewarding aspect is the chance to facilitate meaning-making of course-related conceptual knowledge embedded within an SSI that is (i) relevant to the instructor, students, and team, and (ii) provides an avenue of inclusion for each student and rewards their investment in the process (17).

TABLE 1 Writing-to-learn curriculum module components, implementation logistics, and the application of an inclusive learning framework after Dewsbury and Brame (13)

WTL module component	Key implementation team member(s)	Setting	Inclusive learning
SSI: Introduce a socio-scientific issue (SSI) that resonates with students (10, 14)	Instructor, with knowledge of students	Introduce in class	Promoting engagement and self-efficacy: Emphasizing the relevance of coursework to real life enhances student interest, particularly for minoritized and lower-performing students.
Readings: Select accessible and engaging reading materials that include concepts studied in class	Instructor, teaching/learning assistants	Discuss in class, post on the course online platform	Promoting engagement and self-efficacy: Emphasizing the relevance of coursework to real life enhances student interest, particularly for minoritized and lower-performing students.
WTL prompts: Design a series of three prompts to explicitly invite students to personally reflect on the SSI from a cognitive, affective, and behavioral lens	Instructor	Assign in class, post on the course online platform	Fostering sense of belonging: Interventions designed to support students' feelings of self-worth and integrity can increase academic outcomes for some underserved students.
WTL assignments: Students choose how to respond to the WTL prompts as they organize their thoughts as free writes and/or graphic organizers (15, 16)	Students	Homework, submitted to the course online platform	Promoting engagement and self-efficacy: Supporting students' sense of autonomy by giving students choice and control can increase their interest and enjoyment in a course and decrease anxiety measures.
Peer review: Provide opportunities for peer feedback	Students	In lab (synchronous) or online (asynchronous)	Fostering sense of belonging: Interventions designed to help students understand and endorse growth mindset have been shown to improve outcomes for some underserved groups.
WTL assessment: Award points for the completion of WTL assignments	Teaching/learning assistants	Outside of class/lab, use rubric within the online course platform	Promoting engagement and self-efficacy: Increasing course structure through graded out-of-class assignments and in-class active learning improves outcomes for all students but can have disproportionately large effects for some underserved groups.
WTC assignment: Assign a WTC essay asking students to justify a decision they would make regarding the SSI	Instructor, with knowledge of students	In class and post on the course online platform	Promoting engagement and self-efficacy: Emphasizing the relevance of coursework to real life enhances student interest, particularly for minoritized and lower-performing students.
WTC assessment: Score the WTC essays	Teaching/learning assistants	Outside of class/lab, use rubric within the online course platform	Promoting engagement and self-efficacy: Increasing course structure through graded out-of-class assignments and in-class active learning improves outcomes for all students but can have disproportionately large effects for some underserved student groups.

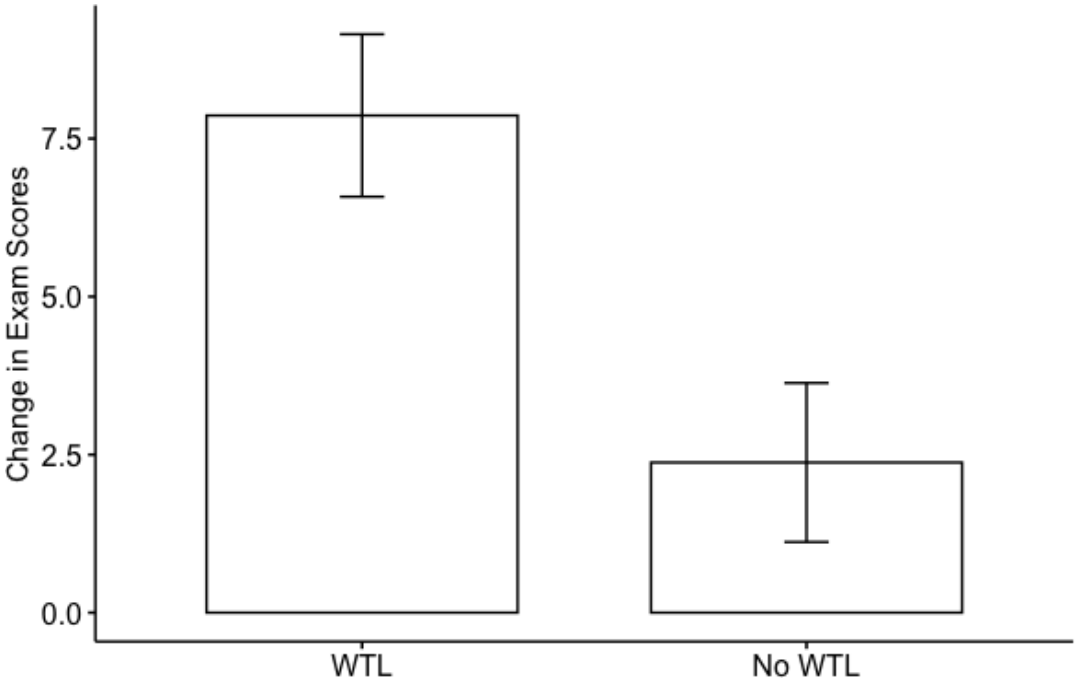

FIG 1 Means and SEM of the changes in exam scores from the first exam to the final exam for students in the WTL semester ($M = 7.9$, SD = 12.0, and $N = 88$) and the non-WTL semester ($M = 2.4$, SD = 12.4, and $N = 97$). Mean exam score changes were significantly higher in the WTL semester, $F(1,177) = 8.09$, $P < 0.005$.

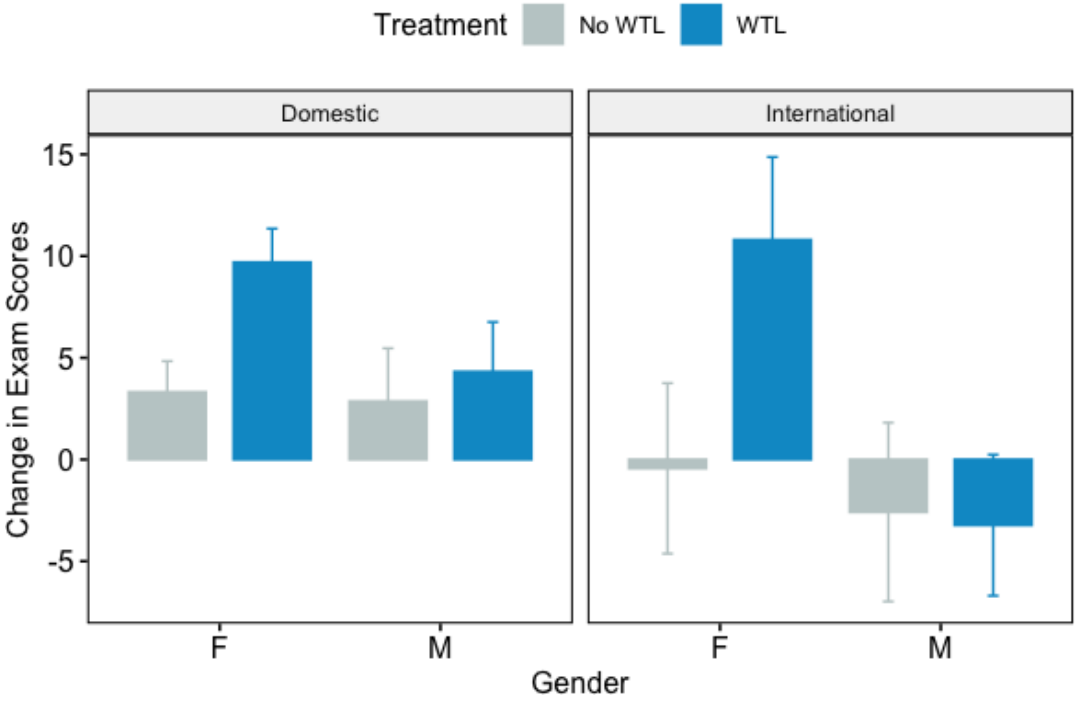

FIG 2 Means and SEM of the changes in exam scores from the first exam to the final exam by gender (male or female) and status (domestic or international) in the WTL semester and the non-WTL semester. Domestic female exam score gains in the WTL semester were higher [*post hoc* comparisons using the Tukey HSD were significantly different for domestic females in the WTL semester ($M = 9.7$, SD = 12.0, and $N = 53$) vs the non-WTL semester ($M = 3.3$, SD = 10.2, and $N = 48$)], and a nearly significant similar pattern was found for international female students ($U = 27.5$ and $P = 0.057$) in WTL semester ($M = 10.8$, SD = 12.9, and $N = 10$) vs the non-WTL semester ($M = -0.4$, SD = 13.9, and $N = 11$).

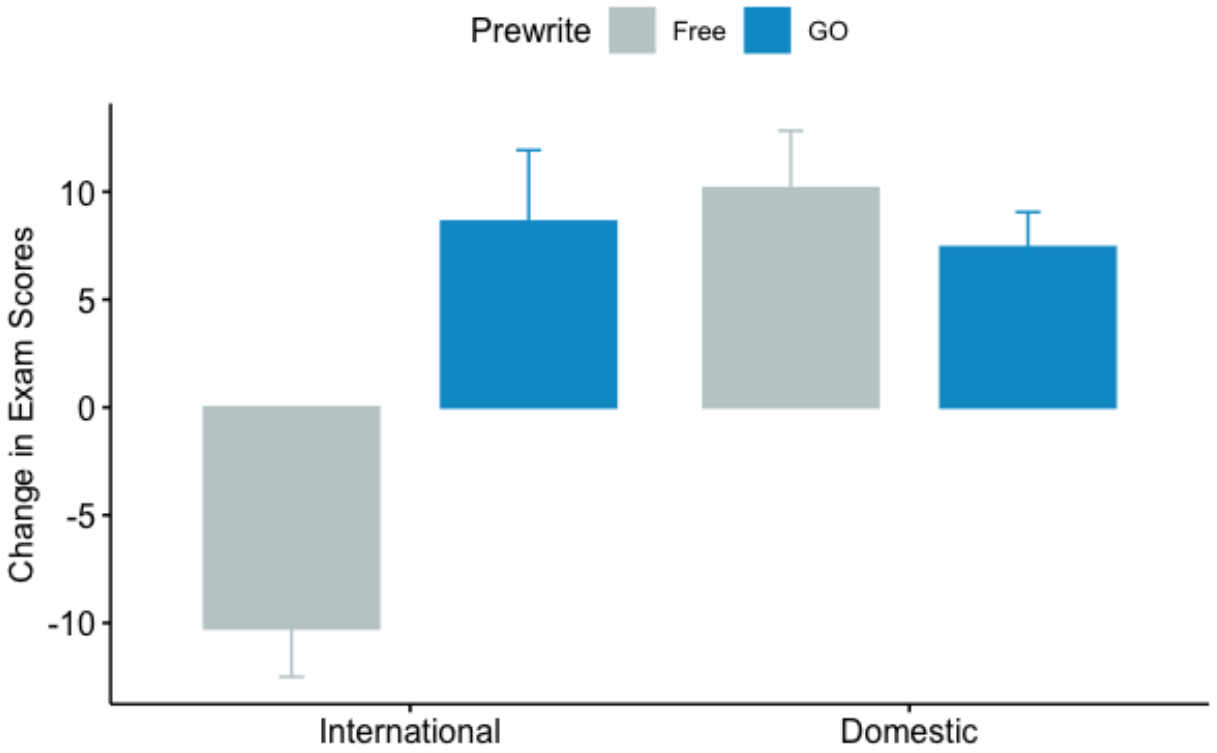

FIG 3 Means and SEM of the changes in exam scores from the first exam to the final exam by prewrite choice ("Free" = free write or "GO" = graphic organizers) and domestic or international students in the WTL semester. The interaction effect was significant, $F(1, 177) = 5.1$, $P < 0.05$, indicating a greater difference for international students. Those using graphic organizers ($M = 8.6$, SD = 12.0, and $N = 13$) showed higher exam score gains than international students using free writes ($M = -10.2$, SD = 3.2, and $N = 2$).

CONCLUSION

A WTL field test in an introductory biology course at a public liberal arts university, based on protocols outlined in a related study (9), demonstrated their effectiveness on student performance. Three-way ANOVA results showed higher exam score improvements in the WTL semester than in the non-WTL semester (Fig. 1), especially female students and potentially female international students (Fig. 2).

We were also interested if students who chose to include GOs in their WTL assignments displayed any patterns in exam score gains. International students (primarily non-native English speakers) who chose GOs greatly improved their exam scores (Fig. 3). We posit there is an opportunity to further examine the use of GOs as WTL interventions for non-native English speakers.

While we have tested these WTL interventions in several educational settings, our original focus investigated writing products for patterns in the development of scientific literacy through the use of evidence, framing, and argumentation (10, 11). Extending our investigations to include student performance measures, we found an association between WTL assignments and improvement of exam scores, particularly among minoritized students. A growing awareness in the field of biology education research of the need to illuminate strategies for more inclusive classrooms (18) reaffirms the benefits of WTL. They provide ample opportunity for deliberate practice and inclusive engagement, components of the "heads and hearts" hypothesis posed to explain the variation in active learning impacts on the performance of minoritized students (3).

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Alison Wallace, Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Supervision, Validation, Visualization, Writing – original draft, Writing – review and editing | Theresa Barosh, Data curation, Writing – review and editing | Ellen Brisch, Data curation, Investigation, Methodology, Project administration, Writing – review and editing | Paul Laybourn, Methodology, Writing – review and editing | Meena M. Balgopal, Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Supervision, Writing – review and editing

DATA AVAILABILITY

Data are archived in https://dspace.library.colostate.edu/handle/10217/172990.

ETHICS APPROVAL

All data collected for this study complied with the approved Institutional Review Board protocol through Colorado State University (123675H).

ADDITIONAL FILES

The following material is available online.

Supplemental Material

Supplemental material (jmbe00087-23-S0001.docx). WTL assignment schedule.

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