2024 NABT Biology Education Research Symposium

DISCOURSE AND ARGUMENTATION PROMOTES LEARNING DURING COLLABORATIVE GROUP EXAMS

S. Katherine Cooper, Jillian Arzoumanian, Michelle Osovitz, and Jeffrey Grim, University of Tampa, Tampa, FL; Suann Yang, SUNY Geneseo, Geneseo, NY

Subject/Problem

Student-centered pedagogies are diverse, yet universally result in positive outcomes for students (Freeman et al., 2014; Theobald et al., 2020). A common thread to student-centered pedagogies is peer interaction, in which group work facilitates student learning, satisfaction, performance, and engagement (Connell et al., 2016; Weir et al., 2019). Two-stage testing using collaborative group exams (CGEs) leverages these peer interactions to convert high stress/high stakes assessments into meaningful and engaging opportunities for student learning. Foundational work from our group (REDACTED) and others (*e.g.*, Karkhanis and Turowski 2015, as cited in Kirkland and Karkhanis, 2017; Knierim et al., 2015) provides evidence that CGEs enhance student performance and learning. Less clear is an understanding of *why* these approaches work so well.

Our current study focuses on student feedback to elucidate if sociocultural engagement (Vygotsky's Theory - Vygotsky, 1978) underpins the performance gains seen with CGEs. Specifically, we used a mixed methods approach to ascertain what students perceive they are learning and how they perceive learning occurred in courses that used CGEs. We hypothesize that discourse and argumentation (i.e., "the articulation of informal reasoning"; Sadler, 2006), during peer interactions are the mechanisms responsible for the positive effects of CGEs.

Design/Procedure

All participating courses utilized high stress/high stakes summative examinations to evaluate student performance. Assessments were given in two stages: 1) an individual exam and 2) a collaborative group exam (CGE). For individual exams, students independently completed the assessment. During the subsequent class period, groups of students collaborated on an identical or similar exam assessment. For all courses, the student's overall exam score was calculated as a weighted average of the two exams (75% individual and 25% for CGEs). Assessment format, question types, and quantity given during the course were determined by individual instructors. Likewise, instructors were given autonomy to tailor implementation of CGEs in ways best aligned with teaching philosophies and course design.

The two-stage CGE methodology was implemented across the non-major and major biology curriculum at REDACTED (a medium-sized private PUI), encompassing 31 sections of 15 distinct courses during the 2022-2023 academic year. Participating courses delivering content primarily through instructor guided in-person lectures. A total of 834 students participated in the study.

Data Collection

We used a mixed-methods approach to investigate the causal mechanisms for the broad effectiveness of CGEs, which also responds to the call by Dolan (2015) for DBER 2.0 - research that moves beyond "answering the question of whether *it* works" to "knowing what is happening during *it* that makes it work."

DISCOURSE AND ARGUMENTATION PROMOTES LEARNING DURING COLLABORATIVE GROUP EXAMS

After each CGE, students completed a Qualtrics® survey including questions related to perception of and experience with CGEs. Survey included 11 Likert-item questions and six open-ended questions. Data collection was approved by REDACTED IRB (IRB #22-032). A subset of questions allowed students to self-report on what they perceive of their learning during the CGE. First, quantitative data was collected on a 5 point scale from students' responses to a Likert-item (Q4), "*I learned new information during the collaborative group exam*". The responses ranged from "Always" to "Never". Following Q4, students provided qualitative data by responding to related questions: "*If yes, give an example of what you learned and how you learned it*" and "*If no, why do you think you didn't learn anything new?*" (referred to as Q4.1 and Q4.2 respectively). For each student, we also recorded course type (general ed, majors, introductory/upper division), academic year/ major, and prior experience with CGEs.

Analyses

Quantitative data were analyzed through an ordinal regression with a cumulative link mixed model (CLMM). Academic year, course level, and prior participation in CGE were fixed effects, and student identifier and course number were random effects. Only perception data from students who completed both an individual and CGE and also had a corresponding metric of exam performance were analyzed (n = 614). The ordinal regression was performed using R (v4.3.0; R Core Team, 2023) and RStudio (RStudio Team, 2023) using the *ordinal* package (Christensen, 2022). Tests for predictor significance were conducted with the *RVAideMemoire* package (Hervé, 2023), and R^2 values were produced using the *performance* package (Lüdecke et al., 2021).

Qualitative student response data (Q4.1 and Q4.2) were analyzed using an inductive approach, with multiple close readings, to explore emergent themes. After removing the missing data for the Exam 1 survey, there were 462 valid responses for Q4.1 and 69 valid responses for Q4.2. Analysis of these data was guided by a grounded theory approach (Charmaz, 2014). First, analysis began with a "preliminary soak" (Hall, 1975:15) by reading all the responses without coding, allowing us to familiarize ourselves with the general tone, length, and types of topics included in student responses. Next, we began coding the data in two stages. "Initial coding" occurred during several close readings of student responses. Following identification of a few initial prominent themes (*e.g.*, student learning through peer discussion), we then conducted the second phase of more in-depth "focused coding" (Charmaz, 2014). During the second coding phase, initial themes and codes were adjusted, refined, and expanded. Throughout the qualitative analysis, we also engaged in a process of analytic memo writing, allowing us to continuously reflect on our insights from the data and (re)analyze comparisons and connections as themes emerged (Charmaz, 2014).

Findings

Quantitative Results

Quantitative results show that students across all courses overwhelmingly agreed that collaborative group exams enhanced their learning. In response to Q4, *"I learned new information during the collaborative group exam"*, 74.6% of students on the first exam responded either "Always" or "Most of the time." Students were 7.3-times more likely to report positive sentiments compared to neutral/less positive sentiments (About Half the Time|Most of the Time: odds ratio = 1.99, 95% CI: 1.36-2.62). None of the investigated fixed effects such as academic year, course level, or prior participation were significant predictors of student response (conditional R^2=0.41; $p > 0.05$ for all fixed effects).

DISCOURSE AND ARGUMENTATION PROMOTES LEARNING DURING COLLABORATIVE GROUP EXAMS

Qualitative Results

Our inductive qualitative analysis of the 462 valid Q4.1 responses ("*If yes, give an example of what you learned and how you learned it*") yielded three main themes related to students' perceived learning (Figure 1):

1. **More than half of students provided specific examples of content they reportedly learned during the CGE.**

When student participants were asked to provide an example of something they learned during the first collaborative group exam Q4.1, 232/462 students (50.2%) named a specific term or concept related to biology. Examples range from "How energy is being used throughout the body" (introductory-level biology student), to "I learned a new fact about cell permeability during the group exam" (upper-level biology student). A subset of Q4.1 student responses, 35/232 (7.6%), recalled a specific fact about concepts or terms learned during the CGE. For example, one first-year student in an introductory-level course responded, "I learned that buffers do not make substances more basic, they just keep the substance at the same pH. I learned this through one of my peer's reasonings." Similarly, a senior enrolled in an upper-level biology course noted, "I learned more about how smaller animals have a higher cost of locomotion and how that affects metabolism." Although these student responses are not indicative of test performance or a measure of knowledge gained, it is nonetheless promising that 50.2% of students who responded felt confident to identify a topic they feel like they learned about during the CGE. Many additional students also reported learning something without the mention of a specific term or concept.

2. **Many students discussed learning through group discussion, by hearing group members explain uncertain concepts, and by learning from one's previous mistakes on the individual exam.**

Students reported that during CGEs, they are learning by hearing their group members explain information in ways that resonate, and through collaborative discussion of topics. Students also specified that it was helpful not only to hear the correct answer in the group discussion (which allowed them to realize and reflect on their own mistakes), but also to hear from their classmates about *why* the answer is correct. Peer feedback, clarification through discussion, and comparing ideas, seem especially beneficial to students' perceived learning of content. Overall, 182/462 (39.4%) of student responses to Q4.1 specifically mentioned their group as beneficial to their learning in their response. For example:

- "Classmates were able to explain it in their own ways which helped me understand." (Junior Biology major in upper-level biology course)
- "Group members drew out diagrams that helped explain their reasoning." (Sophomore Biology-Pre Health major in introductory-level biology course)
- "At one of the questions, I thought we were talking about one thing but after I was corrected, they were able to explain it to me and allowed me to understand it." (Junior Biology major in upper-level biology course)
- "I learned more about a lot of the concepts I didn't understand on the individual exam. For example, when me and my group mates were stuck on an answer, we would discuss which helped me learn new information from my peers." (Sophomore Allied Health major, Introductory-level class)
- "I learned through my group mates who informed me on why my answer was wrong and helped me understand the right answer." (Sophomore Pre-Nursing major, general education biology course)

- "I learned that one of my individual answers was wrong by one of my group members explaining what they put and why, which made me realize that their answer made more sense than mine did." (Junior Biology major, upper-level biology course)
- "There were some questions that I was not confident on, but other people were so I learned how they arrived to their answer [*sic*]." (First-Year, Non-degree-seeking, introductory-level biology course)

3. A smaller but sizable proportion of students stated that they are learning various soft skills, such as teamwork, organization, and studying habits.

Some students also indicated that they were learning various soft skills during CGEs, including teamwork, time management, and study tips to prepare for future exams. Overall, 45/462 student responses (9.7%) to Q4.1 indicated that they were learning at least one soft skill. For instance, a first-year student commented: "It honestly makes you work in a team. Everyone hears others opinions and together find the common answer. I would say you learn teamwork and get to meet people that could make a study group for next exam [*sic*]." Interestingly, one of the most frequent soft skills discussed by students are strategies to become better test-takers. For example, a first-year student enrolled in a general education biology course responded that they "Learned how to fully take in the information of a question before I answer it," and a Sophomore in an introductory-level biology course wrote, "I learned new ways to think through application problems." Others mention strategies for answering multiple choice questions, such as "How to intelligently narrow down my answer choices" (Junior, upper-level biology course), or "breaking down confusing questions by breaking it down and writing it out" (First-Year student, introductory-level biology course).

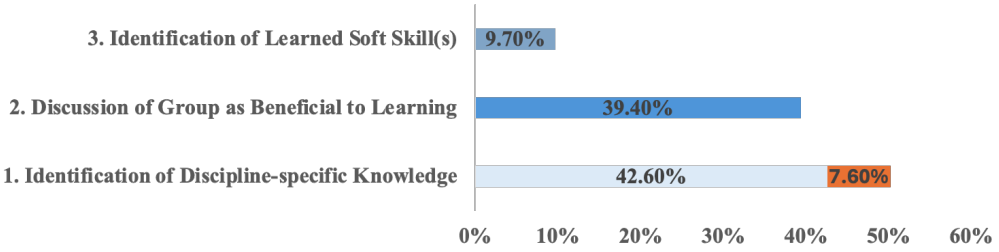

Figure 1. Three themes emerging from qualitative analysis of student responses to Q4.1 *"If yes, give an example of what you learned and how you learned it."* 462 valid responses analyzed. For theme one, responses are differentiated between identified learned concepts (light blue) and identified specific disciplinary facts (orange). Double-coded student responses means the total percentage ≠ equal exactly 100%.

Our analysis of the 69 Q4.2 student responses ("*If no, why do you think you didn't learn anything new?*") found three general themes characterizing how students answered this question. Some students (n=30) responded that they were already well-prepared for the exam to begin with (*e.g.*, "I knew the content pretty well so there wasn't much that I was unsure of."). Also, students also expressed that they (n=10) had already seen the questions in the individual exam and therefore didn't perceive they were discussing new information (*e.g.*, "the exam was the exact same exam as the non-collaborative one"). Lastly, students did not think they learned anything new because the group members that they were partnered with did not provide access to new information. Most (n=12) under this theme asserted that their group members knew the same amount of information as they did—sometimes because they grouped up with their study partner—and so no new information was introduced in the group. An additional 7 students commented that their group did not participate equally. Eight of the 69 responses to Q4.2 (11.6%) actually instead affirmed that the student did learn something (*e.g.*, "I did learn something new").

DISCOURSE AND ARGUMENTATION PROMOTES LEARNING DURING COLLABORATIVE GROUP EXAMS

Contribution

Our work offers valuable insight into the student experience during CGEs, identifying that the opportunity for discourse and argumentation contributes to positive student outcomes. The student responses quite clearly convey the importance of peer-to-peer conversation as they work collaboratively towards a final answer and "learning" – evidence that the peer interactions at the heart of CGEs are an effective way to apply the sociocultural theory of learning, which posits that human learning is largely a social process (Vygotsky, 1978). Our findings also support the use of CGEs as a way to incorporate discourse and argumentation in STEM curricula. Discourse and argumentation allows one to develop a better and deeper understanding of academic content and therefore achieve learning gains (Sadler, 2006; Reznitskaya and Gregory, 2013; Asterhan and Schwarz, 2016). CGEs have many characteristics of the Argumentation for Learning (AFL) framework proposed by Asterhan and Schwarz (2016). For example, our qualitative results show support for the characteristics of dialogue that lead to learning gains - deliberative (ideal discourse that involves listening to and evaluating each other's explanations) and disputative argumentation (defending a viewpoint and seeking to undermine the views of others that differ) rather than consensual co-construction (no challenging or ideas or juxtaposition of alternatives). This makes it plausible that CGEs "work" because they provide the opportunity for these specific interactions to occur, underpinning why peer interactions are critical for learning.

Acknowledgments

This study was supported by the REDACTED Office of Undergraduate Research and Inquiry (OURI) Grant No. 3273 and the Summer Undergraduate Research Fellowship (SURF) Grant. We would also like to acknowledge the wonderful instructors that agreed for their courses to participate in this study.

References

Asterhan, C. S. C., & Schwarz, B. B. (2016). Argumentation for Learning: Well-Trodden Paths and Unexplored Territories. *Educational Psychologist*, *51*(2), 164–187. https://doi.org/10.1080/00461520.2016.1155458

Charmaz, K. (2014). *Constructing grounded theory* (2nd ed.). Sage Publications.

Christensen, R. H. B. (2022). ordinal - Regression Models for Ordinal Data. R package version 2022.11-16. https://CRAN.R-project.org/package=ordinal

Connell, G. L., Donovan, D. A., & Chambers, T. G. (2016). Increasing the Use of Student-Centered Pedagogies from Moderate to High Improves Student Learning and Attitudes about Biology. *CBE Life Sciences Education*, *15*(1), ar3–ar3. https://doi.org/10.1187/cbe.15-03-0062

Dolan, E.L. (2015) Biology Education Research 2.0. *CBE-Life Sciences Education*, *14*, 1-2.

Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences - PNAS, 111*(23), 8410-8415. https://doi.org/10.1073/pnas.1319030111

Hall, S. (1975). Introduction. In A. C. H. Smith (Ed.) *Paper voices: The popular press and social change, 1935–1965* (pp. 11–24). Chatto & Windus

Hervé, M. (2023). RVAideMemoire: Testing and Plotting Procedures for Biostatistics. R package version 0.9-83. https://CRAN.R-project.org/package=RVAideMemoire.

Karkhanis, D. G., & Kirkland Turowski, T. (May 2015). Group exams improve student learning.

Psychology Teacher Network, 25(2), 8-10 http://www.apa.org/ed/precollege/ptn/2015/05/may-ptn.pdf

Kirkland, T., & Karkhanis, D. (2017). Want Your Students to Learn More? Test Them in Groups! [Blog post]. Retrieved from http://noba.to/akdch4mu

Knierim, K., Turner, H., & Davis, R. K. (2015). Two-stage exams improve student learning in an introductory geology course: Logistics, attendance, and grades. *Journal of Geoscience Education, 63*(2), 157-164. https://doi.org/10.5408/14-051.1

Lüdecke, D., Ben-Shachar, M., Patil, I., Waggoner, P., & Makowski, D. (2021). performance: An R package for assessment, comparison and testing of statistical models. *Journal of Open Source Software, 6*(60), 3139. https://doi.org/10.21105/joss.03139

R Core Team (2023). R: A language and environment for statistical computing. R Foundation 5 for Statistical Computing, Vienna, Austria

Reznitskaya, A., & Gregory, M. (2013). Student thought and classroom language: Examining the mechanisms of change in dialogic teaching. *Educational Psychologist*, *48*(2), 114-133.

Sadler, TD. (2006) Promoting discourse and argumentation in science teacher education. *Journal of Science Teacher Education*, *17*(4), 323–346. https://doi.org/10.1007/s10972-006-9025-4

Theobald, E. J., Hill, M. J., Tran, E., Agrawal, S., Arroyo, E. N., Behling, S., Chambwe, N., Cintrón, D. L., Cooper, J. D., Dunster, G., Grummer, J. A., Hennessey, K., Hsiao, J., Iranon, N., Jones, L., Jordt, H., Keller, M., Lacey, M. E., Littlefield, C. E.,...Freeman, S. (2020). Active learning narrows achievement gaps for underrepresented students in undergraduate science, technology, engineering, and math. *Proceedings of the National Academy of Sciences - PNAS, 117*(12), 6476-6483

Vygotsky, L. S. (1978). Mind in society: The development of higher psychological processes Cambridge, Mass.: Harvard University Press

Weir L.K., Barker M.K., McDonnell L.M., Schimpf N.G., Rodela T.M., Schulte P.M. (2019) Small changes, big gains: A curriculum-wide study of teaching practices and student learning in undergraduate biology. PLoS ONE 14(8): e0220900. https://doi.org/10.1371/journal. pone.0220900