STUDENT PERCEPTIONS OF GROUP WORTHY TASKS IN PROOF-BASED COURSES

Christine K. Austin
Texas State University
caustin@txstate.edu

Sharon K. Strickland
Texas State University
ss67@txstate.edu

Kathleen Melhuish
Texas State University
melhuish@txstate.edu

Carlos Acevedo
Texas State University
cia24@txstate.edu

This report presents initial findings from a project aimed at enhancing equitable group work in undergraduate proof classes. The study explored student perceptions of these tasks compared to traditional group work, addressing questions about engagement and collaboration. Quantitative analysis, utilizing the Assessing Student Perspective of Engagement in Class Tools (ASPECT) instrument, indicated overall positive perceptions of the tasks. However, qualitative analysis signaled that structured task designs acted as a key factor in supporting collaboration and understanding. However, varying attitudes towards assigned roles suggest the need for further investigation into their impact on participation. This research underscores the importance of intentional task design in creating equitable learning environments in proof-based courses.

Keywords: Undergraduate Education, Reasoning and Proof, Equity, Inclusion, and Diversity

Overview & Purpose

In this report, we share some initial findings from the project Structuring Equitable Participation in Undergraduate Proof (STEP UP) aimed at supporting more equitable groupwork in undergraduate proof classes. Groupwork is becoming an increasingly common part of undergraduate proof classes with professional organizations (Saxe & Braddy 2015; the MAA Instructional Practices Guide, 2018) advocating for more student-centered approaches in undergraduate instruction. In fact, a recent survey of abstract algebra instructors found that over 90% used groupwork at least once in their course (T. Fukawa-Connelly, personal communication; Johnson et al., 2019). While groupwork can support richer student engagement, it is also a space where participation can be very imbalanced and students perceived as having higher status may dominate (e.g., Cohen et al., 1999; Esmonde, 2009). Proof-based courses have high potential to amplify status differences as students are enculturated into a new language and form argumentation (Weber & Melhuish, 2022) and where competence may be misperceived as unidimensional: ability to produce a formal proof (Hanna, 1991). Thus, there is a need to think about not just the quality of mathematics in tasks, but the nature of the activities and how the tasks may be designed to better support equitable participation.

During the first year of the project, we supported 10 mathematics instructors in designing tasks using principles of Complex Instruction (Cohen et al., 1999; Featherstone et al., 2011). For the scope of this report, we focus primarily on group worthy features of interdependence and individual responsibility. During the fall, four mathematicians implemented between 1 and 3 of these tasks designed for Topology, Linear Algebra, Analysis, and Introduction to Proof, respectively. To explore how students experienced these tasks, we take a mixed methods approach. The students took a brief Likert-scale survey, the Assessing Student Perspective of Engagement in Class Tools (ASPECT) (Wiggins et al., 2017), designed to capture group work experiences. We then interviewed 11 students to both better understand their survey responses and get more in-depth information about their groupwork experiences. For the scope of this paper, we focus on the following research questions:

- RQ 1 In general, how do students perceive the STEP UP tasks in their proof classes?
- RQ 2 How do students perceive differences between their typical group work and STEP UP task days?

Background Literature & Theoretical Perspectives

There is a lot of potential for active learning and groupwork to support students in developing rich understanding and engaging in mathematical practices. However, the literature is mixed on the relationship between inquiry and equity in proof-based courses. For example, Laursen et al. (2014) showed more affective gains for women in inquiry-based classes; Johnson et al. (2020) found that inquiry-oriented abstract algebra was associated with men, but not women, outscoring a national sample on a conceptual assessment. Johnson et al. (2020) conjectured that groupwork may lead to a gendered hierarchy where men engage in a disproportionate amount of the mathematics. Brown (2018) further illustrated the ways that group work may serve to marginalize certain students in an inquiry class in which two women were "excluded" from participating in the group work. From our preliminary work, we have found that men may hold more authority during group work tasks (Hicks et al., 2020; Melhuish, Dawkins et al., 2022). Ernest et al. (2019) identified explicit instances in which student discourse was overtly sexist as well as implicitly aggressive towards women during small-group interactions in an inquiry setting. These scholars problematize the notion that group work necessarily creates equitable learning spaces, when in fact "small-group work can provide fertile ground for inequities to emerge" (p. 168). These results are consistent with K-12 literature establishing the presence of group work in classrooms as insufficient for fostering more equitable learning environments (Cohen et al., 1999; Esmonde, 2009a; Langer-Osuna, 2016; Shah & Lewis, 2019). When students discuss mathematics in small groups, status hierarchies may form, positioning some students as more expert helpers and others as novices in need of help (Esmonde, 2009b).

With these results in mind, we take the position that status, which is influenced by societal factors such as race and gender and comprised of both academic status (perceived mathematical ability) and peer status (social status and popularity) impacts opportunities to engage and learn in the classroom (Cohen & Lotan, 2014). If groupwork does not include features that may disrupt a status hierarchy, then it is likely that high status students will participate the most and thus learn the most. However, specific structures built into group work tasks have the potential to mitigate problematic status hierarchies from forming (Cohen & Lotan, 2014; Dunleavy, 2015; Esmonde, 2009a), which can reduce (rather than amplify) inequities in inquiry settings (Shah & Lewis, 2019).

In our work, we have emphasized a series of principles to support tasks being group worthy in proof classes stemming from complex instruction (e.g., Cohen et al., 1999; Featherstone et al., 2011) and an expansive view on proof activity (Melhuish, Vroom, et al., 2022; Weber & Melhuish, 2022). We consider a task to be group worthy if it allows for *multiple access points* and strategies, foster a sense of positive *interdependence* among group members, and have *structures to hold the group responsible for the participation and learning of each team member* (Cohen & Lotan, 2014). In the context of a proof-based class these structures need to be paired with opportunities for competency to expand beyond proof construction to include activities such as comprehending proofs, building and reasoning from examples, and comparing and modifying proofs (Melhuish, Dawkins, et al., 2022). That is, not only should tasks include social structures (such as group roles or different students being provided with different information), but the nature of the tasks needs to allow for students to engage in mathematics in different ways to support the recognition of different strengths at play. We conjectured that these features could support more positive group experiences that are less dominated by pre-existing status perceptions.

Methods

This data comes from a larger project STEP UP supporting proof-based instructors in designing and implementing more equitable group tasks. In general, the project borrows heavily from complex instruction and notions of group worthy tasks (e.g., Cohen et al., 1999; Featherstone et al., 2011). During summer workshops, instructors who teach different courses collaborated to design tasks where students engaged in theorem and proof comprehension, theorem and proof comparison and analysis, and proof construction (via conjecturing a major theorem and developing lemmas from visual representations.) The tasks were designed to elicit an array of mathematical strengths. They were all embedded with specific roles (e.g., definition manager) and/or responsibilities (e.g., become an expert on proof A, lead discussion about the focal question on your index card). The tasks were designed so each student had mathematical responsibility for components of the activity and that different needed knowledge was distributed throughout the group.

Sample and Procedure

The central research design for this study is an exploratory mixed method (Creswell & Plano Clark, 2011). The purpose for this method is for the qualitative data to explain the quantitative results. We include a quantitative instrument: Assessing Student Perspective of Engagement in Class Tools (ASPECT; Wiggins et al., 2017) and follow-up interviews to better understand and explain the student responses to the ASPECT instrument.

Students were recruited to participate in this study after their instructor (Fall 2023 and beginning of Spring 2024) agreed to run these group work activities in their proof-based courses. In all, we had 76 students consent to participate. Students who consented were recorded (all but one class) in their group work and asked to complete the ASPECT survey either directly after their groupwork task or the following class day. One class, Topology, completed 3 groupwork tasks, the Fall Intro to Proof course completed two tasks, and the Linear Algebra and Real Analysis completed one task. Thus, some students took the ASPECT survey three times. For this analysis, only their first ASPECT scores were analyzed.

Quantitative Measure and Validity Evidence. ASPECT is a 16-item construct with three factors: 1) value of activity (9 items), personal effort (3 items), and instructor contribution (4 items). The measure was designed to assess a student's perception of engagement in an active-learning classroom on a Likert scale (1 = *Strongly Disagree* to 6 = *Strongly Agree*). In this case, ASPECT was used to measure a student's perception of engagement regarding the STEP UP tasks. Only the first factor (value of activity) was utilized. The instrument has been previously validated in an introductory biology course. We used Rasch modeling to assure the validity of the tool in our context focusing on the value of the activity subdomain. An initial item analysis from the first survey responses (n = 77) indicated a slightly less than acceptable item reliability of .72 (above .80 is considered a high reliability index) and an item separation of 1.62 (less than 2.00 suggests a lack of breadth in item difficulty) for the 9-item sub-construct. However, as the score is over 1.5, it is not demeaning (Ariffin at al., 2010) even though it may not distinguish to the desired degree. Despite this, the psychometric results indicate that the data fits the model from the average infit ($MNSQ = 1.00, Z = -.20$) and average outfit ($MNSQ = 1.03, Z = .00$). Our person reliability was slightly above the ideal threshold (above a .80) with a .85, but an ideal person separation (greater than 2 suggests a range in abilities of the students) of 2.34 (Linacre, nd). The Wright Map (Figure 1) displays the spread of the participants (top) on the horizontal scale illustrating the variability in responses.

Follow-Up Interviews. Towards the end of the semester, we sent a survey to all three courses asking students who would volunteer to participate in individual interviews about their interactions with groupwork. We conducted 11 semi-structured interviews with all who volunteered: 5 students from the Introduction to Proof course, 4 students from the Topology course, and 2 students from the Linear Algebra course. We conducted interviews after their finals and interviewed students online via Zoom. During the interview session, there was one researcher leading the interview while a second researcher was taking notes.

The interviews lasted close to an hour, and we had an interview protocol composed of three major parts. The first part asked students to describe their experiences with typical group work, such as their description of the group work that happened in class and their interactions with their group members. The second set of questions in the interview were almost identical to the first part but were focused on the group work from the STEP UP tasks (e.g., thinking back to the tasks on the video recorded days, how do you think this group work was the same or different compared to a typical day?). The last part of the interview centered on asking the participants to elaborate on their reasoning for their score on certain survey items (e.g., could you elaborate on what you meant by this score to the statement: I made a valuable contribution to my group during the Proof Activity?). We shall note that all 11 interviewees were present on at least one day when the STEP UP tasks occurred.

Analysis methods

We report on the results of the Rasch analysis and present some descriptive statistics from the survey. We situated our interview participants based on the scores. For the qualitative portion, the first stage of analysis involved using the interview notes and going back to the video-recorded interviews. For each interview, one member of the research team identified all the instances that a student described a typical workday and instances of explaining the groupwork on the project day. For each individual, a set of key quotes were selected from the transcripts that provided insight into how group work was perceived and how project groupwork days were seen as similar or different. The next stage involved condensing themes (Braun & Clarke, 2006) based on whether the students were discussing either cognitive (learning) or social (participation) features. Additionally, we attended to whether the sentiment was positive or negative based on linguistic cues used to signal appraisals (Eggins & Slade, 2004).

Analysis and Findings

Quantitative Results

Rasch modeling was chosen over a classical approach due to Rasch transforming raw data into continuous data via a logistic transformation (Bond & Fox, 2015). The Rasch model utilizes the response patterns from the item and participants to create a logistic model to transform the data into logits (Bond & Fox, 2015). The visual spread of the logits can be seen in Figure 1 on the Wright Map. To note, typically a Wright Map is displayed as a vertical scale, here we report the map on a horizontal scale. The students on the right of the map (top squares and triangles) are interpreted as more favorable or seeing more value towards the STEP UP tasks. As seen on the Wright Map, the logit score of the students (M = 1.21, SD = 1.38) are higher, on average, than the items (*M* = 0.0, *SD* = 0.29). This suggests that most of the students are scoring these items highly (Likert scale value 4 or above) and agreeing to the value of the STEP UP tasks. As for the items, we see that the items are clustered together towards the left end of the horizontal scale. In Rasch, this means that these items are easier to endorse or agree with by the participants. In other words, all items are interpreted as agreeable. Since there are no items toward the right of the horizontal scale, this suggests that there aren't any items, as a whole, that are predicted by the model to illicit a disagreeable response. While ideally the mean Logit scores of the items and the participants are meant to be near each other, this suggests that the students are favorable of the [BLIND] groupwork tasks created and implemented in these courses.

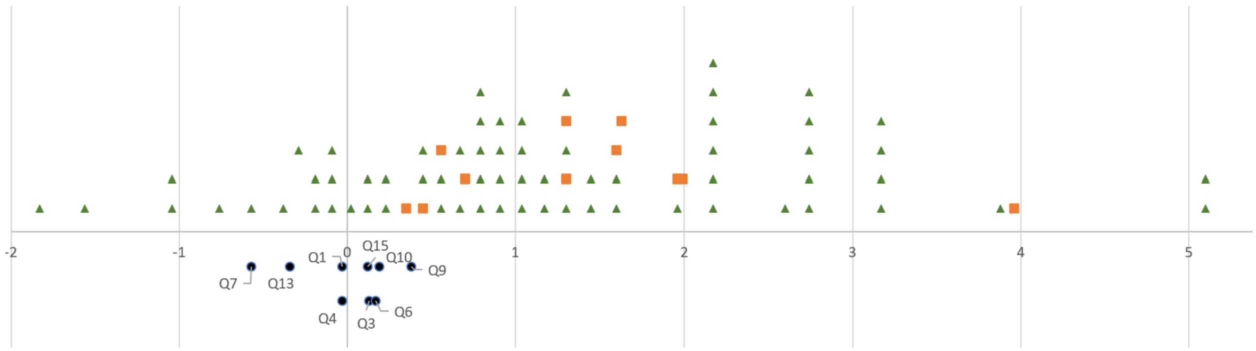

Figure 1. Wright Map

For this subscale, there were two items we focused on which were Q4 (group discussion during [the activity name] contributed to my understanding of the material) and Q9 (I would prefer to take a class that includes [group activity] over one that does not include this group activity). As seen from the Wright Map (Figure 1), item Q4 lies in the middle of the cluster which indicated that this item is agreeable (*M* = 4.59, *Mdn* = 5, *SD* = 1.38) but not as agreeable as item Q7 (the left most item on the horizontal scale). Item Q9 is the right most item on the horizontal scale. This means that item Q9 (*M* = 4.26, *Mdn* = 4, *SD* = 1.51) is not as agreeable or as likely to endorse as Q4. However given its position on the Wright Map, the Likert statement is still likely to be agreed with by the majority of the participants but less favorable than others with a median response of a 4 (neutral to agree).

Table 1: Interview Participants

Participant	Gender	Race/Ethnicity	Course	Score
Alexis	Woman	White	Topology	3.88
Lily	Woman	Hispanic	Topology	1.99
Lee	Man	Asian/Mongolian	Linear Algebra	1.96
George	Man	White	Intro to Proofs	1.60
Crocodile	Man	Hispanic/Latino	Intro to Proofs	1.60
Karli	Woman	Not Provided	Intro to Proofs	1.30
Gabi	Woman	Mixed/Latina	Intro to Proofs	1.30
Joy	Woman	Hispanic	Intro to Proofs	0.67
Julia	Woman	White	Topology	0.56

Joe	Man	Spanish	Topology	0.45
Marla	Woman	Not Provided	Linear Algebra	0.33

To understand some of the results from the ASPECT survey, we interviewed 11 students (Table 1). Our sample of students had a higher ASPECT logit average (*M* = 1.43, *SD* = 1.02) than the whole samples group (M =1.21, SD = 1.36), but still represented a true subset as seen by the Wright Map (Figure 1). On the Wright Map, the interviewed students are represented by the squares and the rest of the participants are represented by the triangles. More about the participants and their ASPECT scores can be found in Table 1.

Qualitative Results

Our goal with the qualitative analyses was to both validate the survey responses and provide more explanatory insight for students reported positive or negative experiences. We subdivide these results into two sections: cognitive-focused and participation-focused.

Cognitive-Focused: Understanding and Activity. None of the interviewed students reported any negative impact of the tasks on their cognitive understanding of the content. Five students identified overtly positive distinctions for the project tasks they felt resulted in differences in understanding the material. Students commented on the structured nature of the tasks with Lily further elaborating, “I honestly just really liked the activity. I felt like it really helped my understanding... that was one of the concepts in the class that I felt like, really, like confident about” with Gabi similarly commenting on structure and the role of having a goal: “So, like in a typical group work, you didn’t necessarily have a goal. It was just more like talking.” Two other students commented on the nature of the activity with Alexis noting that the activity, “made me look at proofs differently, and made me understand a little bit more about like what like a professor or other mathematician might be seeing when they are reading a proof,” and George explaining that their groups helped “explain things in a way that made sense” and supported visualizing.

We see these comments as focusing on three elements: the structured and goal-oriented nature of the tasks, the atypical type of activity (e.g., proof comprehension), and the role of peers. We highlight that the students explicitly noted the “structured” nature of the task in supporting understanding and contrasted it with “just talking.” While structuring the task was an initial design element, this is language students spontaneously introduced during the interview.

Finally, we note that not all students had positive reflections about supporting understanding. Several students still preferred lecture over any group work (although this did not impact their understanding of the material.) Joe indicated that he read the material in advance and suggested he did not benefit in the activity to the degree that students who had not prepared may have.

Participating-Focused: Collaboration and Contributions. Nearly all of the students mentioned differences in participation. Many of the students commented on roles and responsibilities supporting more equalized and collaborative involvement where Joy noted, “I think it [participation] was well spread out because we followed the jobs [group roles]. I think they helped with making sure [we were] learning the entire thing and making sure …we all stuck to contributing. I think if there weren't roles, one of us would have definitely wanted... to step up [meaning take over the work] after seeing how lost all of us were at the beginning.” Other students commented that the group work was “more collaborative (Marla)” and that the roles led to “everyone getting involved (Karli).” Students again noted how the tasks were structured differently with Lily explaining how in typical group work they just have a set of exercises to finish, but the structure of the [blind tasks] meant they had to "share it with each other and compare, and all of that stuff that made, you know, made me have to share it-- made others have to listen to what I have to say as well."

A few commented on people who tended to share a lot on typical days, but who did not share as much on project task days. Marla described a "leader" who would tell others what to do, they would do it, and he would check their work. She noted that on the project task day, this student was given a non-leader role and when the group members traded out roles he did not want the leader role. It is possible he felt some relief from an unintended role he fell into and then didn't know how to navigate away from on his own.

Some students suggested they liked certain structures more than others. "I really loved the first and the third one a lot, a lot, a lot, a lot. The second one-- I think the structure was confusing, and so I felt like we had to slog through a little more. But I actually don't remember the activity very much. I remember the roles, and that they were confusing (Alexis)." Lily compared "free range" group work to "not as much freedom" in the project tasks due to the roles. She further elaborated that because they each had different information (via their roles) and they had to combine it to find an answer, she "didn't mind" and compared it to solving a mystery.

In contrast, there was one student who voiced a negative reaction to the task structure. George explained, "It was frustrating that I couldn't contribute, because I might have already known the answer." Other students noted that they stepped back during some role activities or wished they had a larger role or a different role (one student said her group switched up roles right away so everyone got what they wanted). However, George was the most direct about feeling the structured task roles held him back. In that interview he commented that he'd hear a groupmate say something wrong and would want to correct them, but didn't feel his role allowed for that. The same student also noted, "Yes, yes, I've never had an issue with respect in the class. I would hope that I properly respected everyone in the class as well. Again. It's hard for me sometimes to tell if I'm being disrespectful. It's not something I'm very good at." He did not elaborate and it's entirely possible he has some differences in interpreting social cues and nuance in how others perceive statements. It also may be helpful for this student to practice restraining from correcting others—however, it is not a task design intent to ban anyone, despite group role, from speaking up or commenting on others' thinking.

Discussion and Conclusion

This study provides initial evidence that structures from K-12 group work can be successfully integrated into undergraduate proof-based contexts. As group work becomes an increasingly common part of advanced mathematics, it is crucial that we consider how we implement it to not amplify status issues that are particularly prevalent in proof-based classes. To address this issue, we developed task templates (stemming from an earlier exploratory abstract algebra context, Melhuish, Dawkins et al., 2022) that disrupted what types of activities students are asked to engage in by moving away from traditional proof construction as the primary task, and integrated intentional structures to support interdependence and personal responsibility. The quantitative results from this study suggest that across four classes, students by-and-large reported positive experiences with the STEP UP tasks. The interviews then shed light on what students perceived as key differences between typical group work days and STEP UP tasks and the ways the STEP UP tasks did or did not support learning and collaboration. In this way, we are contributing to Adiredja and Andrews-Lasron's (2017) call to better understand student experiences in active learning to gain insights into what circumstances may support positive experiences.

All students noted at least one difference between project task groupwork and regular groupwork—almost all had something to do with the structured nature, which they contrasted with "just talking" in typical groupwork. Students who appreciated this structure suggested it led to more collaboration, better understanding, and appreciated having a clear goal in mind. Most students indicated they felt the structures did equalize participation in terms of different student contributions. However, we note that the roles were most divisive and most brought up in the interviews. The students who were explicit about usually being chatty, not having any problem jumping into conversations, or self-identified as strong mathematically commented either an ambivalent relationship to the roles (liked them here; not there) or did not like them (the one student who described them as frustrating). It may be that some students like roles because they have a harder time jumping into discussion and others feel less positive because they did not usually have a hard time. Our theoretical view on status may provide insight into this relationship. We conjecture that the "high status" students may feel more constrained when not left to dominate conversation.

Because the data in this study is all self-reported, we are limited in terms of making conclusions about actual participation rates and nature of collaboration. In future research, we plan to consider empirically the contribution rates in groups to examine the degree that status appears to predict or not predict contributions. Additionally, we are bringing positioning lenses in to explore not just participation rates, but how students are engaging with each other and the mathematics. This initial phase of the research points to several promising avenues for continued work in developing more equitable group work situations in proof-based classes. We suggest other researchers who engage in design of classroom tasks at this level consider not just how to support cognitive and activity goals, but also what structures may support increased involvement and collaboration of all students in small groups.

References

Adiredja, A. P., & Andrews-Larson, C. (2017). Taking the sociopolitical turn in postsecondary mathematics education research. International Journal of Research in Undergraduate Mathematics Education, 3(3), 444-465.

Ariffin, S. R., Omar, B., Isa, A., & Sharif, S. (2010). Validity and reliability multiple intelligent item using rasch measurement model. *Procedia-Social and Behavioral Sciences*, *9*, 729-733.

Bond, T. G., & Fox, C. M (2015). Applying the Rasch model: Fundamental measurement in the human sciences (3rd ed.) Routledge.

Brown, S. (2018). E-IBL: An exploration of theoretical relationships between equity-oriented instruction and inquiry-based learning. In A. Weinberg & C. Rasmussen, J. Rabin, M, Wawro, & Brown, S. (Eds.). Proceedings of the 21st Annual Conference on Research in Undergraduate Mathematics Education (pp. 1–15)

Cohen, E. G., & Lotan, R. A. (1995). Producing equal-status interaction in the heterogeneous classroom. American Educational Research Journal, 32, 99–120.

Cohen, E. G., Lotan, R. A., Scarloss, B. A., & Arellano, A. R. (1999). Complex instruction: Equity in cooperative learning classrooms. Theory into practice, 38(2), 80-86.

Creswell, J. W., & Plano Clark, V. (2011). Designing and conducting mixed methods research (2nd ed.). Sage.

Dunleavy, T. K. (2015). Delegating mathematical authority as a means to strive toward equity. Journal of Urban Mathematics Education, 8(1), 62-82.

Eggins, S. & Slade, D. (1997/2004). *Analyzing Casual Conversation.* Equinox, United Kingdom.

Ernest, J. B., Reinholz, D. L., & Shah, N. (2019). Hidden competence: Women's mathematical participation in public and private classroom spaces. Educational Studies in Mathematics, 102(2), 153-172.

Esmonde, I. (2009a). Ideas and identities: Supporting equity in cooperative mathematics learning. Review of Educational Research, 79(2), 1008-1043.

Esmonde, I. (2009b). Mathematics learning in groups: Analyzing equity in two cooperative activity structures. The Journal of the Learning Sciences, 18(2), 247-284.

Featherstone, H., Crespo, S., Jilk, L. M., Oslund, J. A., Parks, A. N., & Wood, M. B. (2011). Smarter together! Collaboration and equity in the elementary math classroom. National Council of Teachers of Mathematics.

Johnson, E., Keller, R., Peterson, V., & Fukawa-Connelly, T. (2019). Individual and situational factors related to undergraduate mathematics instruction. *International Journal of STEM Education*, *6*, 1-24.

Johnson, E., Andrews-Larson, C., Keene, K., Melhuish, K., Keller, R., & Fortune, N. (2020). Inquiry and gender inequity in the undergraduate mathematics classroom. Journal for Research in Mathematics Education, 51(4), 504-516.

Langer-Osuna, J. M. (2016). The social construction of authority among peers and its implications for collaborative mathematics problem solving. Mathematical Thinking and Learning, 18(2), 107-124

Linacre, J. (n.d.). Reliability and separation of measures. Retrieved February 7, 2024, from https://www.winsteps.com/winman/reliability.htm

Laursen, S. L., Hassi, M. L., Kogan, M., & Weston, T. J. (2014). Benefits for women and men of inquiry-based learning in college mathematics: A multi-institution study. Journal for Research in Mathematics Education, 45(4), 406-418.

Mathematical Association of America (MAA) (2018). MAA Instructional Practice Guide. Washington, DC: Mathematical Association of America.

Melhuish, K., Dawkins, P. C., Lew, K., & Strickland, S. K. (2022). Lessons learned about incorporating high-leverage teaching practices in the undergraduate proof classroom to promote authentic and equitable participation. *International Journal of Research in Undergraduate Mathematics Education*, 1-34. https://doi.org/10.1007/s40753-022-00200-0

Melhuish, K., Vroom, K., Lew, K., & Ellis, B. (2022). Operationalizing authentic mathematical proof activity using disciplinary tools. *The Journal of Mathematical Behavior*, *68*, 101009. https://doi.org/10.1016/j.jmathb.2022.101009

Saxe, K., & Braddy, L. (2015). A common vision for undergraduate mathematical sciences programs in 2025. Washington, DC: Mathematical Association of America.

Shah, N., & Lewis, C. M. (2019). Amplifying and attenuating inequity in collaborative learning: Toward an analytical framework. Cognition and instruction, 37(4), 423-452.

Weber, K., & Melhuish, K. (2022). Can we engage students in authentic mathematical activity while embracing critical pedagogy? A commentary on the tensions between disciplinary activity and critical education. *Canadian Journal of Science, Mathematics and Technology Education*, *22*(2), 305-314. https://doi.org/10.1007/s42330-022-00221-6

Wiggins, B. L., Eddy, S. L., Wener-Fligner, L., Freisem, K., Grunspan, D. Z., Theobald, E. J., Timbrook, J., & Crowe, A. (2017). ASPECT: A survey to assess student perspective of engagement in an active-learning classroom.