Fostering Grade 9 Girls' Sense of Belonging Through the Use of Collaborative Lab Practicums as Authentic Assessments in Science

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Abstract

In 2023, the gender gap in STEM remains significant, with women making up only 28% of the STEM workforce (UNESCO, 2023). Research suggests that fostering a sense of belonging in secondary Science classes is an effective strategy for increasing and sustaining the participation of girls in the STEM pipeline (Hansen,2023). The three guiding principles for a student to have a sense of academic belonging are interpersonal relationships, disciple identity, and a growth mindset (CELT Teaching Briefs). This action research project investigated how collaborative lab practicums, as authentic assessments, cultivated discipline identity, and promoted a growth mindset, to foster a sense of belonging for girls in a Grade 9 Physics classroom. The research, conducted at The Spence School, an all-girls K-12 institution, employed a mixed-methods approach, combining Likert-scale surveys, field observations, video recordings, and interviews. Twenty-nine Grade 9 students participated in this study. Findings indicate that collaborative lab practicums deepened students' understanding, and promoted collaborative learning. Students valued the hands-on, real-world application of theoretical knowledge, which facilitates a deeper connection to science. Additionally, the collaborative nature of the assessments encouraged teamwork and enhanced communication skills. The majority of students exhibited a growth mindset, emphasizing the importance of redoing and revising calculations as part of the learning process. While challenges, such as the fast-paced nature of practicums, were noted, overall, students expressed a preference for this collaborative, authentic learning approach. This study contributes valuable insights into fostering a positive sense of belonging in the Science classroom which could ultimately increase the participation of girls in the STEM pipeline.

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Research examining interventions in education aimed at addressing STEM pipeline "leakage" has identified a sense of belonging as a crucial element in retaining girls' interest and engagement in STEM fields and careers (van den Hurk, 2018). Fostering an environment where girls feel valued, supported, and included, can mitigate the challenges that often deter them from pursuing STEM pathways.

Diversity in the workforce contributes to creativity, productivity, and innovation. Women's experiences and perspectives—along with men's experiences—should inform and guide the direction of science, engineering, and technical innovation. Increasing the representation of women in STEM fields not only brings economic and social advantages but also fosters a more equitable society. One prominent benefit is the advancement toward narrowing the gender pay gap and the development of more inclusive products and services tailored to female needs. We cannot afford to ignore the perspectives of half the population in the future.

A widely accepted definition of a sense of belonging in an academic setting comes from Goodenow (1993):

> A sense of belonging is defined as being accepted, valued, included, and encouraged by others (teachers and peers) in the academic classroom and of feeling oneself to be an important part of the life and activity of the class. Students' sense of belonging has been identified as a potential lever to promote success, engagement, and well-being in college. (p.80)

Evidence and research suggest that there are many teaching practices and strategies to foster a sense of belonging. However, at its heart, three key guiding principles must occur for a student to have a sense of academic belonging. These are interpersonal relationships, discipline identity, and growth mindset (Center for Excellence in Learning and Teaching, 2021).

Assessments serve as the bridge between teaching and learning and enhance learning when the assessment tasks are set in a realistic context and require application. McTighe (2020) states that assessments should provide opportunities for students to work with others and where the teacher acts like a coach. Performance-based assessments include activities which result in students producing tangible results to demonstrate their learning and require application, rather than recall (McTighe). Furthermore, performance-based assessments are sometimes referred to

as “authentic assessments,” a term popularized by Grant Wiggins (1990). Authentic assessments present students with “a genuine challenge, a target audience, and realistic constraints, and result in a tangible product of performance that serves as evidence of students’ understanding and proficiency” (McTighe, p. 27). In addition, McTighe emphasizes that the performance task should reveal the students’ ability to transfer knowledge, “to use what they know in a new situation” (p. 65).

Collaborative lab practicums are performance-based assessments aimed to enhance students' practical understanding of physics concepts through hands-on tasks in a collaborative setting. For this action research project, using a mixed methods approach, I wanted to examine the effectiveness of collaborative lab practicums in fostering a sense of belonging in a Grade 9 Science classroom.

Action research was an ideal methodology for studying collaborative lab practicums aimed at fostering a sense of belonging due to its iterative and participatory nature. Unlike traditional research methods, action research emphasizes active involvement from both researchers and participants throughout the entire process. This approach allows for continuous reflection, adaptation, and refinement of strategies based on real-time feedback and insights gained from the collaborative experience itself. By engaging directly with participants, action research ensures that the study's findings are not only theoretically sound but also practical and relevant to the context of the lab practicums. Moreover, its focus on collaboration aligns well with the goals of the project, facilitating a deeper understanding of the dynamics at play and fostering a sense of ownership among participants, ultimately leading to more effective interventions for enhancing belongingness within the lab environment.

Literature Review

Collaborative lab practicums enable students to problem solve collaboratively and apply their scientific knowledge to new situations. The collaborative nature of the assessment eases student anxiety and empowers them to try different approaches to complete the task (Ioannou & Artino, 2008). Chi et al. (2021) conducted a comparative study between hands-on and traditional methods of assessment and concluded that hands-on assessments provide students with opportunities to demonstrate and apply their scientific knowledge and skills by constructing solutions rather than recalling facts.

The effectiveness of hands-on performance tasks (authentic assessments), and their many benefits, has been widely studied in the literature. Efu (2019) analyzed 16 empirical studies from various disciplines and investigated the extent to which collaborative assessments improve learning outcomes. Of the 16 studies, nine found collaborative assessments improved student learning, while seven found no difference between the students who completed their exams individually or in groups. Efu states that while there may not be a consensus in the literature, there are several benefits of collaborative assessments beyond improvement in knowledge and exam performance, including a decrease in student anxiety about exam performance.

Additionally, Sokhanvar et al. (2021) and Singer et al. (2020) found through extensive literature reviews that authentic assessments can play a significant role in improving student engagement and equipping students with essential communication skills, collaboration skills, critical thinking and problem-solving skills, self-awareness, and self-confidence. In a separate study, Ioannou and Artino (2010) echoed Efu's findings and stated that collaborative assessment can promote collaborative learning, mitigate test anxiety, and make in-class testing a more positive educational experience.

Another significant outcome of authentic assessments is the cultivation of students' discipline identity specific to science or their STEM identity. Hazari et al. (2010) studied how students' physics identities are shaped by their experiences in high school Physics classes and found that high school still provides a "window of opportunity" (p. 980) to meaningfully engage some female students who were not previously interested in physics. The study identified the frequency of labs that address students' beliefs about the world, the frequency of students commenting and answering questions, the frequency of students teaching classmates, and teacher encouragement as factors which are positively related to physics identity for students.

Collaborative lab practicums enable students in small groups to work in a lab setting to collect data to solve a problem and allow them to apply their theoretical knowledge to real-world situations while discussing solutions and answering questions. It is another form of authentic assessment. Singer et al. (2020) further state that to foster STEM identities, it is important to focus on a sense of belonging, which can be facilitated through authentic learning experiences.

Similar to Hazari et al.'s (2010) findings, Singer et al. (2020), summarized that there are three important contributors to STEM identity formation: teaching for diversity and inclusion through exposure to role models, an individual's sense of belonging to the educational institution

and to the STEM fields, and authentic learning experiences. Eren (2021) conducted a case study where women's science identity development in physics and physical science was investigated via interviews with women pursuing advanced degrees and states, "sense of belonging has been found to be one of the most important determinants of STEM identity development" (Eren, p. 1137). Hence, it can be inferred that collaborative lab practicums offer genuine learning experiences and have the potential to nurture girls' discipline identity, ultimately fostering a sense of belonging among students in the Science classroom.

The design of the collaborative lab practicum inherently promotes a growth mindset since students have opportunities to re-do the task and correct their errors throughout the process. In her book *Mindset,* Carol Dweck (2016), a noted psychologist states:

> In a growth mindset, people believe that their most basic abilities can be developed through dedication and hard work—brains and talent are just the starting point. This view creates a love of learning and a resilience that is essential for great accomplishment. (p.52)

Thus, teaching students about a growth mindset could be a powerful tool for improving the participation of females in STEM fields. Kramer et al. (2023) studied the effects of explicitly teaching about growth mindset theory, activities that connected theory to success in STEM, and a guest speaker to provide a real-world example of a woman with a successful career in STEM and her ideas about how growth mindset beliefs related to her success. The study found that the high school girls who received these interventions had a statistically significant change toward more growth-oriented beliefs compared to the control group.

Authentic assessments are hands-on tasks that provide students an opportunity to recreate, to some extent, the conditions under which scientists work and elicit the kind of thinking and reasoning used by scientists when they solve problems. Thus, collaborative lab practicums can lead to students developing a discipline identity and promote a growth mindset, which can ultimately facilitate a student's sense of belonging in the Science classroom. I contend that if a student experiences a sense of belonging in the Science classroom, it could lead them to pursue science careers; thus, increasing the participation of females in the field of science.

Research Context

The Spence School is an all-girls' K-12 school located in New York. Founded in 1892 by Clara Spence, the School's motto "Not for school but for life we learn" was adopted from the

philosophy of Seneca, the ancient Roman philosopher. The School serves 770 students in Kindergarten to Grade 12 from all the boroughs of New York City. The School is comprised of three divisions the Lower School (K- Grade 5), Middle School (Grade 5- Grade 8), and the Upper School (Grade 9-Grade 12).

Physics is one of the core academic courses for students in Grade 9. In this lab-based course, students are introduced to conceptual and computational aspects of physics. Students engage in lab activities roughly twice a month. Labs are designed to reinforce content and build valuable skills including collaboration. Classes meet for 55 minutes, four times a week. Students are well-versed in designing, carrying out experiments, and communicating their results throughout the year. Three faculty members work in collaboration to design and implement the curriculum. All Grade 9 students participated in collaborative lab practicums but data were only collected from students in my sections (29 students). Parents and guardians were notified about the research through an "opt-out" letter detailing the action and the student's role and participation. Video footage, survey responses, and interview responses were de-identified and coded. Only I had access to all the research material.

The Action

A collaborative lab practicum is a performance-based assessment that requires students to apply knowledge and skills rather than simply recall. I designed collaborative lab practicums as authentic assessments to assess student understanding and to help students discover the interconnectedness of different topics.

Over the research period, students engaged in two collaborative lab practicums: Buggy Collision and Buggy & Marble Collision. The objective of the buggy collision collaborative lab practicum was for students to determine the time and location of the collision between two buggies. Each group was provided with the starting location for their buggy. They then had to work with another group to calculate when and where their buggies would collide. Students were assessed on their ability to determine the velocity of the buggy and then use a system of equations to determine the time and location. Once the time and location were determined, students' predictions were tested and filmed to verify.

The objective of the marble and buggy collision was to determine the time of collision between a constant velocity buggy and a marble in free fall. Similar to the buggy collision, students were given the drop height of the marble and then had to use other measurements and

calculations to determine the starting location of the buggy such that the marble and buggy collided.

While the students were actively participating in the collaborative lab practicums, my role was to check for their comprehension by listening to their interactions. I did not answer student questions since the practicums were framed as assessments. Students had access to their class notes, previous assessments, and materials on the learning management system. Collaborative lab practicums are equitable assessments because when certain students are not able to move forward, I can ask probing questions to guide the students toward an approach or solution. Similarly, for students who were quickly able to strategize and problem solve, I was able to offer an extension for the task or ask them higher-order thinking questions.

Data Collection

To determine the effectiveness of collaborative lab practicums as a tool to cultivate discipline identity and promote a growth mindset, a mixed methods approach was used (Mertler, 2020). Likert scale surveys, field observations, video recordings, and interviews were used to polyangulate the data. Doing so improved the credibility and trustworthiness of the results. Given the nature of action research and the sample size (29 students), qualitative data were collected in response to the research question.

Likert-scale surveys were administered to measure students' STEM identity, perceptions about growth mindset, and attitudes towards collaborative learning twice during the study- at the beginning and end of the project. Additionally, one-on-one structured interviews were conducted and recorded. The classes were also video recorded as students were engaged in the collaborative lab practicums. My mentor and other members of the physics teaching team also observed students as they were engaged in the collaborative lab practicums. Their observation notes supplemented my observations from the video recordings.

Twenty-nine students responded to the three separate surveys: one on perceptions about collaborative learning, one on their STEM identity, and one on growth mindset. The growth mindset survey was based on Dweck's (2006) *The Mindset Quiz*. Responses were scored and categorized as Strong Growth Mindset (61-80 points), Growth Mindset with some Fixed Ideas (41-60 points), Fixed Mindset with some Growth Ideas (21-40 points), and Strong Fixed Mindset (0-20 points), based on the student's scores.

The surveys on perceptions of collaborative learning and STEM Identity were based on different surveys found in the literature hence the scoring and categorization were not standardized.

Students were filmed when engaged with the practicums and also participated in focus group interviews, one after each collaborative lab practicum. The recordings were later transcribed and coded. Field observations were also recorded and coded as were the responses to the structured interview questions. The interview questions focused on the student experience with the collaborative lab practicums namely the collaborative problem-solving process of completing the tasks and the nature of assessment.

Data Analysis

The data were inductively analyzed using a three-step process: organization, description, and interpretation. The survey and interview responses, observations from video recordings, and field notes were coded and organized, allowing for the grouping of data that provided similar types of information and trends (Mertler,2020). Aspects of the data were interpreted to answer the research question. While several patterns were identified in the data consistent with girls' experiences in science classrooms and perceptions about growth mindset as reported in the literature, some student responses and observations that were contradictory are also included in the final analysis.

Discussion of Findings

Four different themes emerged based on student responses across the surveys and focus group interviews, field observations, and video footage of the collaborative lab practicums. While the course evaluations were not part of the research methodology, it is worthwhile to mention that 26 out of 30 students responded that collaborative lab practicums were their favorite part of the course!

Collaborative Learning is Valued Among Students

Survey results and interview responses strongly indicated that collaborative learning is valued among those surveyed. Sixteen out of the 29 surveyed students strongly agreed with the statement that "A collaborative learning environment creates a better opportunity for learning" and students also felt that collaborative learning provides them the opportunity to learn about teamwork and improves their communication skills. Students responded, both in the survey and in the interviews, that the role of the teacher in a collaborative learning environment is to

facilitate the learning process and to guide the students. Student K reflected during the focus group interviews that collaborative lab practicums allowed her to think more and she "can use my group to help guide me in my thinking".

Collaborative hands-on approach to science deepens student understanding

Collaborative lab practicums enabled students to collaborate effectively and apply theoretical knowledge to solve problems in the context of the "real world." During the focus group discussion, Student H commented "[collaborative lab practicums] allowed me to take what I know and use in real life" and Student B said, "When working individually, you don't understand the material because you just want to finish it but during a collaborative lab practicum, one has to really understand the task in order to move forward." Student E commented "collaborative lab practicums don't feel like a lab – it feels like real life and I feel like I am solving a real problem." However, one student (Student R) did comment about the fast-paced nature of collaborative lab practicums and said, "sometimes those feel like one and done, if you didn't understand when you are doing it, then there isn't another opportunity to learn the concepts." Another suggested (Student Q) that if students had an opportunity to reflect the following day and to discuss the process and findings as a class, it would enhance the experience and further deepen their understanding.

Authentic Assessments Cultivate Discipline Identity

Authentic assessments have been defined widely in the literature as "hands-on assessments that provide students with opportunities to demonstrate and apply scientific knowledge and skills by constructing solutions rather than recalling facts" (Chi, et al., 2021, p.1). "Additionally, when students are engaged in "investigations that recreate to some extent the conditions under which scientists work and elicit the kind of thinking and reasoning used by scientists when they solve problems," (Shavelson, et al., 1998, p. 4) it can cultivate a STEM discipline identity (Singer, et al., 2020).

Field observations and video footage show that students actively engaged in the collaborative lab practicums, where they have an opportunity to think and reason like scientists/engineers. To indicate how authentic assessment reflect real-world problems and problem-solving, Student AA remarked, "I like seeing how the equations are used in the real world" during the Marble and Buggy collaborative lab practicum. Another student echoed a similar sentiment and responded "we can use the equations to make things happen!"

Another interaction between Student S, Student B, and Student O during the Buggy Collision collaborative lab practicum is a clear indication of students engaging in critical thinking/reasoning much like scientists. In a dialogue between students, it is clear that they are helping each other develop reasoning skills, and that the task itself - reflective of a real-world problem - helped students see themselves as scientists. Student S said "I think we have to write the equation for each of our buggies" and Student B responded, "Then do we set them to equal to each other to find the time?" Student O then piped up with "and once we find the time, we plug it back into the equation to find the location". Many groups engaged in similar conversations to arrive at a problem-solving approach/methodology. Collaborative lab practicums, as authentic assessments, provide students an opportunity to engage in reasoning and problem-solving processes much like scientists, which in turn could cultivate the students' STEM discipline identity.

Collaborative Lab Practicums Enable Students to Revisit and Revise Calculations

Based on Dweck's *Mindset Quiz* and its categorization, of the 29 respondents, 10 were categorized as Strong Growth Mindset, 15 were categorized as Growth Mindset with some Fixed Ideas, 2 were categorized as Fixed Mindset with some Growth Ideas and 2 were categorized as Strong Fixed Mindset. Thus, it is evident that the majority of the students surveyed already engaged in growth mindset practices.

During the focus group interview, Student D commented "When I am stuck during the collaborative lab practicum, we can always go back and fix it or redo the calculations". The structure of the collaborative lab practicums allows students to identify errors in their thinking or calculations and an opportunity to correct their errors. Secondly, the role of the teacher as facilitator allows the teacher to ask probing questions that can redirect students to correct their mistakes.

Conclusion

For my action research project, I investigated how collaborative lab practicums, as authentic assessments through a hands-on, collaborative approach to problem-solving, can cultivate discipline identity and promote a growth mindset, ultimately fostering a sense of belonging in the Science classroom. The literature suggests that a sense of belonging can affect a wide range of student outcomes, including academic achievement. The literature further provides three guiding principles for fostering a sense of belonging: interpersonal relationships, discipline

identity, and a growth mindset. Data from this action research project indicate that collaborative lab practicums cultivate discipline identity and promote a growth mindset, thus accomplishing two of the three guiding principles for fostering a sense of belonging. Exploring the third principle, interpersonal relationships, was beyond the scope of this action research project.

Despite the positive feedback, challenges such as the fast-paced nature of practicums were acknowledged, suggesting the importance of incorporating reflection sessions and highlighting opportunities for continuous improvement in the design and execution of collaborative lab practicums.

There are several avenues for future research and development. Firstly, further exploration is warranted to understand how collaborative lab practicums can be adapted to accommodate diverse learning styles and paces, ensuring that all students benefit equally from the collaborative approach. Additionally, investigating the long-term effects on students' pursuit of STEM careers and their sustained interest in physics can provide valuable insights into the lasting impact of such interventions. Furthermore, future research could delve into the role of educators in fostering a positive learning environment during collaborative assessments. Lastly, if a reliable method of measuring interpersonal relationships were designed, it would be interesting to study how collaborative lab practicums affect interpersonal relationships.

While this study illuminates the positive outcomes of collaborative lab practicums for girls in Grade 9 Physics, ongoing research and continuous refinement of pedagogical strategies are essential for creating an inclusive and supportive educational experience. By addressing these future directions, educators and researchers can contribute to the ongoing effort to bridge gender gaps in STEM fields and nurture a generation of confident and engaged female scientists and engineers.

Reflection

As a science educator, my objective is to increase and sustain the engagement of young women in STEM fields. I believe that fostering a sense of belonging in Science classrooms during girls' high school years can serve as an effective strategy to encourage and retain women in the STEM pipeline. The hands-on and collaborative nature of the collaborative lab practicums is a valuable intervention to support these efforts. I am inspired to continue exploring innovative teaching practices that foster engagement and identity in Science classrooms. The success of this action research project serves as a reminder of the transformative power of student-centered,

collaborative learning approaches and further fuels my commitment to creating inclusive curriculum and authentic assessments. Moving forward, I am eager to build on these insights, refining and expanding the use of collaborative lab practicums, and contributing to the broader conversation on effective STEM education strategies.

Moreover, the feedback and insights shared by the students during interviews and surveys provided valuable perspectives that further enhanced the research findings. It was particularly rewarding to hear students express how these collaborative experiences didn't just feel like traditional labs but, rather, like opportunities to address genuine challenges. Recognizing that the collaborative lab practicums had become a favorite aspect of the course for the majority of students reinforced the notion that meaningful, hands-on activities contribute significantly to a positive learning environment.

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