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Board 156: Concrete Tools to Practice Diversity, Equity, Inclusion, and Belonging in the STEM Classroom

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Concrete Tools to Practice Diversity, Equity, Inclusion, and Belonging in the STEM Classroom

Introduction

Science, Technology, Engineering, and Math courses are central to producing a highly skilled 21st-century workforce. These classes are also often notorious for being the most challenging courses students take, often existing as gatekeepers that determine the opportunities students have available to them. As a student and a teacher of the sciences, I have become passionate about creating equitable access to the opportunities that STEM majors and thinking can provide students. This paper is written in an autoethnographic style and illustrates the framework that I've developed as a result of my journey in creating resources for science teachers.

I selected the auto-ethnographic method of inquiry for this study based on the constructivist approach I use in my classroom to form meaning for students. This method allows for a nuanced narrative that breaches the traditional concerns of research from generalization across cases to generalization within a case [1]. Creswell and Creswell describe autoethnography as a research methodology that analyzes a phenomenon through the use of self-narratives, which would otherwise remain "private or buried [2]." Autoethnography has allowed me to use my personal experience in teaching, providing professional development, and mentoring teachers to provide a framework that can one day be the subject of more data-driven research [3].

As an educator with a decade of STEM curriculum writing and teaching experience, I have had the opportunity to work in urban Title I schools as well as a school focused on serving neurodivergent students (also referred to as students with learning differences). The student populations I have had the privilege of working with are some of the most innovative and resourceful people, while also being some of the most historically excluded from STEM success.

The world needs these brilliant minds to help come up with divergent solutions to our world's toughest problems. I became determined to find ways to best support my students to feel included, and successful in my own STEM classroom as well as other STEM situations. I started attending any professional development available to me with titles including the words diversity, equity, inclusion, and belonging (DEIB), culturally responsive teaching, and cultural humility. I even attended a talk by the author of Culturally Responsive Teaching and the Brain, Zaretta Hammond.

I became disillusioned by the large sweeps of theory these developments and talks gave without concrete ways for me to use them in my science classroom. Even developments aimed toward science like democratizing teaching and Catalyzing Inclusive STEM Experiences (CISTEME365) lacked concrete ways for me to implement theory long-term in my classroom. CISTEME365 included 5 books of tools, languages, and strategies aimed to increase DEIB in classrooms. All of these tools are incredibly valuable and you will see much of their research in this paper. However, there is a disconnect between all of the tools that are provided and ways to implement them sustainability and consistently in the classroom during a school year.

After spending countless hours researching, discussing, attending fellowships, and professional developments looking for an answer to what diversity, equity, inclusion, and belonging looked like in a high school science classroom, I found the answers were mainly theoretical. This paper sets out to describe the process by which I used these theories to distill a practical, strategy-based, actionable framework for secondary science teachers to use with concrete steps to support their classrooms in becoming spaces that support DEIB.

Framework

The framework I've developed contains 5 elements: intentional grouping, student-driven labs, project-based assessments, presentations, and reflections. These sections were distilled using a combination of classroom experience and research. Each of these elements is powerful on its own but added together they create opportunities for students to build self-efficacy, belonging, and inclusion. These qualities then lead to classrooms that can foster students who can find resilience and joy in diversity and create equitable spaces. The framework I developed is visualized in Figure 1 below. I will describe each of these elements and the research that went into them.

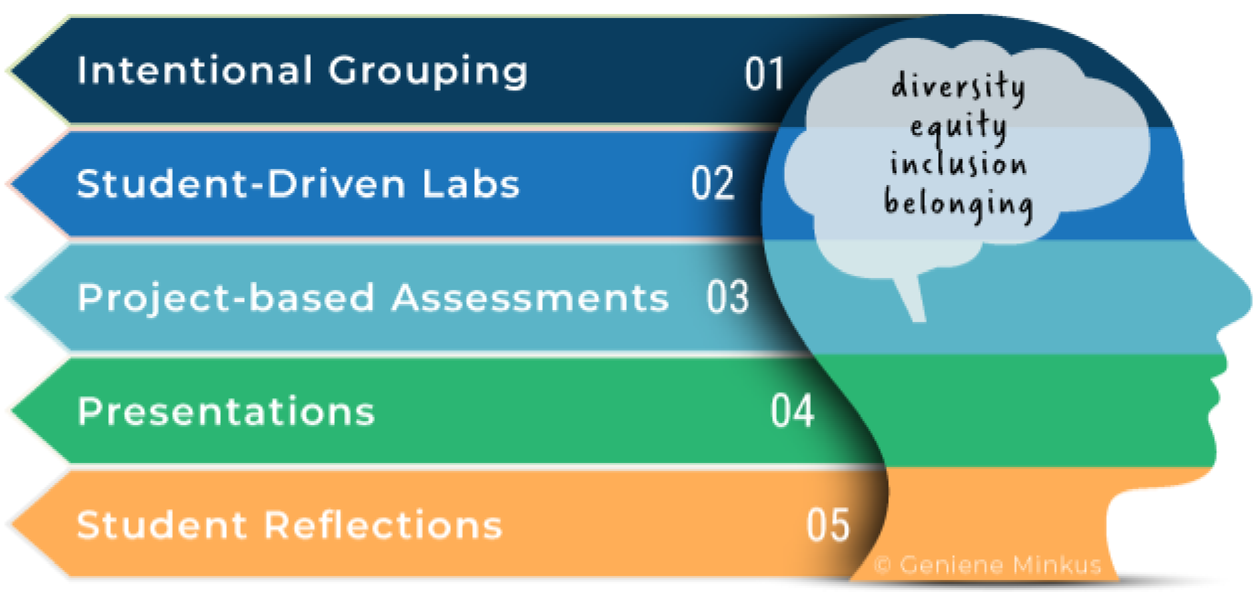

Figure 1. STEM DEIB Classroom Framework

Before the Framework:

While doing research around actionable science DEIB strategies, I encountered and studied social-emotional learning (SEL). While the tenants of following the framework benefit from an SEL background many of those strategies are beyond the scope of this paper. The ability of students to be able to self-identify their emotions and use them appropriately in the classroom is central to community building. Collaborative for Academic, Social, and Emotional Learning (CASEL) does a great job of using social-emotional learning as a vehicle for creating equity. The idea of Transformative SEL is “A process by which young people and adults build strong, respectful and lasting relationships that facilitate co-learning to critically examine root causes of inequity and to develop collaborative solutions that lead to personal, community, and social well-being [4].” This concept is a powerful basis for building DEIB classrooms as it provides a basis for building communities. I will return to the idea of creating an SEL aware classroom in part 5 of the framework.

Part 1: Intentional Grouping

Almost every career-oriented role requires collaboration skills; setting students up for success using intentionally created student-selected groups is an essential start to any culturally aware STEM classroom. Intentional grouping involves several different tools that help teachers ensure student success. Brown, et al, write: “When teachers are mindful of the important aspects of group dynamics, such as size, ability, gender, and race, and plan teams accordingly, every student—particularly those from marginalized backgrounds—is set up for success [5].”

Teachers need to consider the following pieces when creating groups. The first is size, groups should range from 3 to 6, with 4 being an ideal size for most groups [6]. I have found the most success in my classroom giving students 3-4 people to work with. As students get older, I have found that groups of 3 increase success on abstract thinking projects to avoid students pairing off and losing progress. In active STEM classrooms, the traditional knowledge of heterogeneous mixing is replaced by more student success and engagement in homogenous groups. This avoids students of lower levels who “had a strong tendency to defer to [higher level students] that student to let him or her figure things out, and then explain it to them [7].” Finally, race and gender cannot be ignored. Grouping students who share common genders, races, and backgrounds together reduces stereotype threat, and imposter syndrome and empowers students who otherwise might be overshadowed in a traditional classroom setting [8].

In my experience in the science classroom, I have found that grouping students in the same groups throughout a learning unit is most effective. This way students struggle to gain an understanding of their strengths and weaknesses together and can use those as tools in final assessments. They also learn to trust that the effort they are putting into building their team is well spent as their team will work together throughout a unit. It also encourages students to find belonging and equity in their differences as traditionally high students learn to recognize the strengths and contributions of diverse students. I'd go so far as to say in my classroom keeping groups together for units and semesters has driven friendship, success, and community in my classrooms.

Key Strategies:

- Allow students to write on a notecard 2-3 people they want to work with
    - Make your own best choices when assigning final groups
- Change lab groups only when needed. Keep them the same as long as possible.
- Ensuring grouping is aware of size, ability, gender, and race.
- Try homogeneous grouping for active lab groups

Part 2: Student-Driven Labs

Student-driven labs allow the intentional groups created to explore by designing experiments driven by their curiosity. The open-ended nature of these labs requires students to navigate emotionally charged and difficult situations in which students learn to respect each other's intellectual and problem-solving processes. This abstract thinking vs concrete thinking allows students to find themselves on more if not more difficult footing. This allows for the different strengths of different students to shine through. The students who may have struggled with reading and following instructions shine as they try new ways to solve problems. Whereas the more traditional follow the process students are challenged to think in new ways and can show off their strengths in organizing processes. Allowing my students to explore instead of telling them what to do radically changed the experience of my classroom.

In the past two decades science education has moved from traditional "cookbook" labs to inquiry-based labs, and is now moving toward Next Generation Science Standards (NGSS) science and engineering practices. These practices are different from what inquiry-based labs became, as they are not just about asking questions but evaluating the process by which information is discovered, tested, and affirmed [9]. Creating open-ended labs values students' natural curiosity and drive to figure out solutions to problems. A process that values each student's intellectual and problem-solving process [10]. This curriculum is research-based and supported in part by the Illinois Physics and Secondary Schools Partnership Program (IPASS) whose curriculum won the APS award [11]. Their dynamic open-ended problems utilizing a simple measurement device put all students on an equal playing field in solving conceptual problems. Often I’ve found teachers get lost in teaching the content of science, having students memorize the formulas and relationships. Instead, to create DEIB-focused classrooms, teachers should shift to supporting students in developing problem-solving skills that will give them resilience to survive tough STEM classes for the rest of their academic careers.

I have found students in my classroom are initially incredibly uncomfortable with open-ended labs. However, after intentional periods where students are given opportunities to feel safe in failure and experimentation, they grow to value, respect, and demand abstract learning opportunities. I highly encourage teachers to build space for intentional failure when starting an open-ended lab practice with a new group of students. This can look like a day where you ask students to come up with as many different ways to measure something as possible. Or this looks like a project in which the outcome is for students to list as many iterations as possible to get to their final answer. In my classroom, we called it a “PowerPoint party of things tried.” I found that inviting students to celebrate what didn’t work created a culture of experimentation and acceptance that would not have otherwise existed. Meanwhile, some students still struggle with freedom and challenge the pedagogical strategy. I found with purposeful scaffolding, for example, question starters and hints on the next steps to take, they were able to become much more self-sufficient and inclusive learners. This environment fosters a community that embodies the tenets of DEIB and demands them in their classroom communities.

Key Strategies:

- Shift away from using cookbook labs toward student-driven labs
    - Most traditional labs can become open-ended labs
- Give students a statement to prove or disprove the materials available, and let them go for it.
- Give students room to fail, and make it okay, even celebrate it!
- Turn your attention to questioning students in feedback rather than giving them right or wrong answers.

Part 3: Project-based Assessments.

Once I had accomplished a classroom in which students felt comfortable creating investigations, gathering data, and making conclusions my classroom started to suffer from a “now what?” problem. Students were excited about their newfound investigation abilities, but started to ask, what can we do other than labs? Their confidence and demanding nature are a double-edged sword in creating a classroom in which students feel empowered and belong. However, this pushed my teaching and classroom to the next level. I will not say that I reached culturally sustaining teaching in my room all of the time, creating egg drop containers is not that. Sometimes though, the project-based learning (PBL) driven by my student questioning leant itself to students creating solutions to problems they saw within our community. An example of this is creating a butterfly garden based on their studies of Chicago's ecosystem. Or creating a mentoring physics Olympics to support the middle school, science students.

In general, these project-based assessments transformed lab experiences into elevating tools that can impact their communities, in which every student can find multiple unique avenues to success and can elevate practice to be culturally sustaining [5]. As students encounter safety within their standing homogeneous lab groups and learn how to get creative and embrace failure as a learning tool through open-ended labs, assessment becomes more of a climatic event than a fill-in-the-bubble assessment. PBL attempts in my classroom before the first two steps in this framework often fell flat with students grasping for the "right answers" and uncomfortable with the uncertainty of applying their ideas and experimentation. Project-based learning in combination with this framework allowed for an authentic way for me to assess students' science skills, and understanding of topics while having students do science [12]. Brown, et al, write: "A key component of PBL is that it is student-centered, rather than teacher-centered. The teacher is a facilitator, guide, or tutor rather than the "sage on the stage [5]."

Allowing the student to utilize their learning to solve problems in the real world, whether at home, in their communities, or even at school promotes a self-efficacy that supports DEIB classrooms. Science classrooms are great places to allow students to solve community problems with design thinking, which leads to feeling a greater sense of belonging with each other and within their communities.

Key Strategies:

- Work with your students to brainstorm ideas for the project, they will surprise you with how astute they are and the areas in their communities they can use science to serve
- Create weekly plans to support students in open-ended projects, they are still developing, so they will need help with structures, to-do lists, and outcomes necessary for success
- Start with something you're comfortable with! Students love a good egg drop, even if it isn't changing the world.

Part 4: Presentations

At this point, in my DEIB journey, I was feeling pretty great about my classroom. However, as with all classrooms, students adjusted to the new reality and started to miss some of the points I was trying to drive home. Students who had been in their lab groups for most of the year were comfortable and starting to lose comfortability with the iterative process, and connection to the thought processes from outside their bubble of a lab group. In one class I tried changing lab groups as this occurred, this was disastrous. Students felt betrayed and my classroom started to feel like it had in the fall. However, after brainstorming with some teacher friends, and some researchers at the University of Illinois, I realized one critical piece of the scientific process was missing. Students weren't owning their process outside of their groups, or their conversations with me. Further, it became abundantly clear that one of the skills college students were missing was the ability to present their work, explain their process, and identify what could go better next time to important stakeholders. Thus, the presentation portion of my class was born. This isn't just presenting things at the end of a perfect process, it is instead the practice of presenting knowledge as it is created. This fixes the issue of students creating unactionable error feedback and future studies.

Presentations are critical to developing students' ability to communicate in order to protect the DEIB-aware classroom they thrive in. These also empower students to develop communication, argument, and questioning skills they may not otherwise have. Giving students the opportunity to present and receive feedback about their work will increase their self-efficacy and growth mindset. Increasing self-efficacy, "Can be particularly effective for students from marginalized groups who are more likely to doubt their abilities because of the cycle of inequity [13]."

When homogeneous groups of students must give presentations, create arguments and support them we are supporting all students in developing their communication abilities. Traditionally, students can hide behind a private test score, however, creating a community that actively provides feedback and questions to each other is paramount to developing 21st-century thinkers who see value in different ways of viewing problems [13]. This is also a powerful way to restart the scientific process so students can internalize that science as a continuous process of learning new information.

Key Strategies:

- Have students highlight what doesn't work, and support them in celebrating each other's failed ideas.
- Create a system of feedback for students to ask questions, give ideas for solutions and celebrate each other.
- Having a formatted slide deck students can always refer to, takes out the "making presentation pretty time lag" that happens when students go down the rabbit hole of available slide themes.

Part 5: Student Reflections.

With parts one through four in action, students were happily working in lab groups to solve open-ended problems, translating their knowledge into project-based assessments, and presenting their progress, and getting community feedback at regular intervals. Something that I have been testing throughout my teaching career is reflective learning. This has existed in many forms in my classroom, the end-of-semester feedback form, the quiz reflection form, the one on one conversation, and the list goes on…. It wasn't until I had the first four pieces of the framework in place and working that I was able to standardize individual reflections for students in what was a meaningful way.

Individual student reflections ensure students have the space to do metacognition necessary to impact their trajectories [14]. "Teaching practices congruent with a metacognitive approach to learning include those that focus on sensemaking, self-assessment and reflection on what worked and what needs improving [15]. Allow students the opportunity to reflect on what they were thinking at the beginning of a process, and what they have learned about themselves, and the problem-solving process is critical. This brings us back to the beginning of the framework when I insisted that social-emotional learning is crucial to creating a DEIB science classroom. Teaching students to identify, and self-describe their thought processes, their success and their failures, how they make them feel, and what they will do differently each time empower students with the tools they need to protect their classroom space and the other students that are a part of the classroom community.

Key Strategies:

If you are going to have students do a reflection make it matter:

- Make the reflection worth a grade
- Have a 1:1 meeting about what they wrote
- Show the reflection to the student again, before you make them do the next one.
- Connect student actions to the natural learning process
- Connect student effort to their outcomes (growth mindset)

The pieces of the framework as individual elements are powerful. However once combined the framework empowers the secondary science classroom to be a space where students can become affirmed in their STEM identities, a crucial element of self-efficacy, and experience feelings of belongingness to the classroom community, a crucial human need [13][16]. Each part of the framework supports the next piece, creating a cyclical framework for how teachers can support science learning while supporting their student's development.

Conclusion

The broader implications of this work are concrete tools that science teachers can use to start building classrooms that support all students. Science teachers are often left out of the larger conversation around equity in the classroom and yet are probably some of the most critical levers to ensuring that all students have the opportunity to pursue diverse, impactful, and lucrative 21st-century careers.

The limitations of this auto-ethnographic study are that it took place in a limited number of classrooms with a limited number of teachers. Expanding this study to be a data-driven study occurring in multiple school settings, with a variety of teachers with a variety of teaching experiences would expand the impact of the framework and validate it across a larger population.

My journey through creating tools to best serve students in the science classroom tells a self-critical and reflective path toward creating an educator tool kit. As the framework is made up of individual pieces that each require teacher-specific refinement I encourage teachers to use this framework as a starting place in their own DEIB classroom journey. For more resources and an expanded social-emotional learning tool kit, please visit genieneminkus.com. Using this framework will support science teachers in building a more resilient and affirmed STEM student.

References

1. Ellis C. & Bochner, A.P. (200). Autoethnography, personal narrative reflexivity: Researcher as subject. In N.K. Denzin & Y.S. Lincoln (eds.), *Handbook of qualitative research* (2nd ed.), 733-768. Thousand Oaks, CA: Sage.
2. Creswell, J. W., & Creswell, J. D. (2017). Research design: Qualitative, quantitative, and mixed methods approaches. Sage publications
3. Belbase, Shashidhar & Luitel, Bal & Taylor, Peter. (2008). Autoethnography: A Method of Research and Teaching for Transformative Education. Journal of Education and Research. 1. 86-95. 10.3126/jer.v1i0.7955.
4. Jagers, R., Borowski, T., & Rivas-Drake, D. (2018). Toward Transformative Social and Emotional Learning: Using an Equity Lens . *American Institutes for Research*.
5. Brown, M., Thompson, J., & Pollock, M. (2017). Ensuring Equity in Problem Based Learning. NAPE. Gap, PA
6. Rosser, S. V. Group work in science, engineering, and mathe- matics: Consequences of ignoring gender and race. College Teaching 46, 82-88 (1998).
7. Briggs, M. (2020). *Comparing academically homogeneous and heterogeneous groups in an active learning physics class*. NSTA.
8. Rosser, S. V. Group work in science, engineering, and mathematics: Consequences of ignoring gender and race. College Teaching 46, 82-88 (1998).
9. Schwarz, C. V., Passmore, C., & Reiser, B. J. (2017). *Helping Students Make Sense of the World Using Next Generation Science and Engineering Practices*. NSTA Press.
10. Yusran, Siswanto, Hartono, Subali, B., Ellianawati, Gumilar, S., & Sartika, D. (2019). What's wrong with the cookbook experiment? A case study of its impacts toward learning outcomes of pre-service physics teachers. *Journal of Physics: Conference Series*, *1280*(5), 052047.
11. *Award for improving undergraduate physics education awardees*. American Physical Society. (n.d.). Retrieved March 2, 2023, from https://www.aps.org/programs/education/undergrad/faculty/awardees.cfm
12. Belland, B. R., Glazewski, K. D. & Ertmer, P. A. Inclusion and problem-based learning: Roles of students in a mixed-ability group. RMLE Online 32, 1-19 (2009).
13. Brown, M., Tucker, C., & Pollock, M. (2017). Inspiring Courage to Excel through Self-Efficacy. NAPE. Gap, PA.
14. Smilkstein, R. We're born to learn: Using the brain's natural learning process to create today's curriculum. (Corwin Press, 2011).
15. How People Learn: Brain, Mind, Experience, and School: Expanded Edition. Washington, DC: The National Academies Press. https://doi.org/10.17226/9853.

16. Maslow, A., & Lewis, K. J. (1987). Maslow's hierarchy of Needs. Salenger Incorporated, 14(17), 987-990.