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Using Visual Notetaking to Promote Participatory Equity in a Science and Math Methods Course

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Abstract

This paper is part of a multi-year project on implementing visual notetaking strategies into undergraduate courses to promote equitable learning experiences, reflexive thinking, divergent thinking, and participatory equity. Here, we define participatory equity as the internalization of a sense of belonging, where teacher educators, learning science and math concepts, can engage with inquiry, intellectual challenge, and uncertainty in a space that utilizes various identity perspectives as assets, minimizing the "I am not good at math/science" mindset. Participants were undergraduate students in a science, technology, engineering, and math (STEM) teacher preparation methods course from six majors (courses of study), with 27% from a STEM discipline, 20% from humanities, and 53% from the social sciences. Visual notetaking exercises were used daily as part of the instructional process to assist students in connecting learning experiences to material reality as they learned about their STEM identities while learning STEM content and instructional design. Visual notetaking facilitated visual representation using visual thinking strategies, recognizing patterns, and defining structures through new notetaking forms. Learning experiences were designed to develop students' conceptualizing of science and math while learning how to design learning for pre-adolescent students. By using visual notetaking strategies, students were able to practice divergent thinking (i.e., possibilities), convergent thinking (i.e., forms that express meaning), and risk-taking (i.e., the vulnerability associated with expression). Qualitative coding of open responses on a post-survey revealed two major themes: 1) Visual notetaking provided a mind space for learning about self, and 2) it provided a calming opportunity to connect concepts. Quantitative analysis indicated significant correlations between focused headspace and notetaking ($r = 0.555$, $p < 0.001$), focused headspace and connecting with others ($r = 0.405$, $p < 0.001$), and using imagination helps me learn and creating visuals helps me learn ($r = 0.528$, $p < 0.001$). In addition, students showed small gains (eta squared = 0.03) on a pre-post analysis on "a safe space for learning." Future work now focuses on what students and professors perceive as possibilities for instruction and what students perceive as possibilities for more profound development of safe-space embodiment, intuition, tolerance, and the co-creation of knowledge.

Keywords: *teaching methods, inclusion, equity, creativity, student engagement, STEM*

Introduction

Science, Technology, Engineering, and Mathematics (STEM) education has been primarily driven by national and state policies focused on fulfilling a perceived deficit in an employment-eligible citizenry to address and meet specific sociocultural needs [1]. The National Science Foundation and federal and state education agencies have been responsible for addressing the deficits (e.g., new standards, funding career pathways) with only a modest increase (2.6%) in doctoral science and engineering students since 2000 [2]. The 2017-19 numbers are dismal for Black and Hispanic workers compared with White (9%, 8%, 67%, respectively). Despite policies designed to promote an increase in overall STEM professions, particularly when trying to increase gender, racial, and ethnic diversity, we ask, what is not working in STEM education?

Indeed, focusing on socioscientific issues does lead to a focus on STEM, but with a lens of deficit thinking (how to fill gaps with STEM training) rather than reframing the issues in sociocultural contexts (the assets cultural beings bring to STEM solutions). Developing a sociocultural-socioscientific position provides an opportunity to deconstruct existing STEM silos [2] and center STEM education in the context of social justice education and participatory equity [3].

Social justice science education reframes learning from *what should be learned* to *sense-making* through intentional dialogs with *self and others* [3]. This reframing humanizes STEM learning by focusing on the intersection between community concerns and science understandings. The focus shifts from the traditional, top-down reductionist model of teaching STEM to a bottom-up model where STEM learning is social-issue driven. This shift orientates learning towards *meaningful* learning, the relation of reality to learned material, and a focus on self and learning processes [1].

Transformative Pedagogy and Situated Learning

How do we implement a new transformative pedagogy that is justice-centered and results in more equitable participation in STEM classrooms? Culturally relevant pedagogy [4], critical pedagogy [5], and problem-based learning [6] provide the theoretical frameworks for transformative pedagogies. The Soil Project focused on a local issue – the long-term environmental impact of a recently closed coal-fired power plant [7]. In the project, high-school students faced a real, local issue. The result of the project and new pedagogy was that students understand environmental racism as a more significant issue, were able to learn STEM concepts and skills through original laboratory work (promoting equitable experiences and expectations), and broadened the students' participation as a service to their community and direct engagement with social justice [7].

The Soil Project provided students with the construct of agency and autonomy. The agency allowed students to take control of their learning [8]. The autonomy was grounded in a sociocultural issue, which fostered an *internal dialog* focused on controlling the learning process and what needed to be learned. The combination of agency and autonomy contributes to the student’s reflexive thinking capacity [9].

Situated learning refers to interactions between self, others, and objects. “Self” describes the space of agency and autonomy within situated learning. “Others” refers to the interactions within the situated space, and “objects” refers to the resources (human and non-human) and content/concepts being learned. The interactions in situated learning flow at the direction of the experience (e.g., teacher-directed curriculum). The degree to which agency and autonomy are permitted is crucial in situated learning. The resulting internal dialog provides opportunities for students to “make discoveries about self,” “discern,” and “deliberate” to place value and priorities on what is being learned and to “commit” based on aspirations, hopes, or desires [9].

Possibility Books - Implementing Visual Notetaking in a STEM Methods Course

“Possibility books” are a form of visual notetaking, sketchnoting, or visual thinking grounded in Mayer and Moreno’s [10] cognitive theory of multimedia learning. Meaningful learning requires discerning, deliberating, and committing to the material's perceived essential aspects. Often, students in STEM classes experience notetaking to capture what was said during lectures – a behavior associated with “being a good student.” Meaningful learning is shared when students can apply what is being taught, engage in problem-solving strategies, and develop mental models of interconnected concepts [10], [11]. Gansemer-Topf, Paepcke-Hjelness, and Russell [12] employed visual notetaking (sketchnoting) strategies in a university ecology course. They defined sketchnoting as “a non-linear, note-taking methodology, following the procedure of listening, synthesizing, and visualizing information, by incorporating building blocks made of language, space, frames & connectors, people, and objects.” What appears to be missing in the ecology course is the critical development of creative thinking, which helps students learn about the tolerance of ambiguity, be open to new experiences and different perspectives, be willing to take risks to explore new possibilities, and discover unexpected connections between concepts and across disciplinary domains.

We implemented Possibility Books in a STEM methods course for undergraduate students interested in becoming teachers. Participants (11) were undergraduate students in a science, technology, engineering, and math teacher preparation methods course from six majors (courses of study), with 27% from a STEM discipline, 20% from humanities, and 53% from the social sciences. Students not majoring in STEM had minimal and often troubled experiences learning mathematics and science. The students in the STEM methods course were part of a more extensive study across the undergraduate institution. During implementation, we determined that the visual notetaking activity was best presented at the start of each class, where students could engage in developing creative thinking skills that could then be used to create mental models while engaging with content. For example, in one activity, students were asked to choose three shapes, three lines, and three colors and then connect each shape, line, and color to their perception of *what it means to learn in STEM spaces*. This helped students consider the importance of *divergent thinking* as a valuable skill for exploring and discerning. Each Possibility Book activity illustrates the creative process, often in the "messy middle" of scientific discovery. The students learned the importance of failing, iterating, and analyzing to try again. The final activity asked students to choose one of two images as a textbook cover for the course and then explain why they chose that particular cover. Connecting with learning often resides in “a big idea.” An activity like this allows students to discern and deliberate on a deeper level as they resolve the “muddy middle” between what is known and what is unknown.

A thirty-three-item questionnaire was developed to determine how Possibility Books were used for notetaking (mark making), how well the books connected learning, how well Possibility Book activities addressed anxiety with learning content, and how well social interaction experiences contributed to overall learning. The questionnaire was given at the beginning and end of the course.

Results and Discussion

An exploratory factor analysis was employed to determine the interrelation among scaled variables. The intent was to reduce the data to fewer items with strong correlations ($r = 0.642$, $p < 0.001$). The result was a ten-item index that described *a Safe Space for Learning (SSL)* (Table 1). A t-test was conducted to evaluate the influence of Possibility Books on creating an SSL. There was a statistically significant increase in SSL scores from the beginning of the course ($M = 50.31$, $SD = 4.54$) to the end of the course ($M = 51.08$, $SD = 5.07$, $t(191) = 2.6$, $p < .005$, two-tailed). The mean increase in SSL scores was 0.77, with a 95% confidence interval ranging from 0.188 to 1.35. The eta squared statistic (0.03) indicated a small effect size.

Through visual notetaking, students were able to practice divergent thinking (i.e., developing possibilities), convergent thinking (i.e., forms that express meaning), and risk-taking (i.e., the vulnerability associated with expression). Qualitative coding of open responses on a post-survey revealed two major themes: 1) Visual notetaking provided a mind space for learning about self, and 2) it provided a calming opportunity to connect concepts. Quantitative analysis indicated significant correlations between focused headspace and notetaking ($r = 0.555$, $p < 0.001$), focused headspace and connecting with others ($r = 0.405$, $p < 0.001$), and using imagination helps me learn and creating visuals helps me learn ($r = 0.528$, $p < 0.001$).

Qualitative data was also analyzed using structural and thematic coding derived from the SSL index: how the Possibility Book activities contributed to learning and how the activities promoted community. For knowledge construction, the primary theme was the ability to “think abstractly” and “create drawings” to represent abstract concepts. For example, one student wrote, “I liked that a couple of tasks asked us to think abstractly and create abstract drawings to represent what we know about math. This changed my perspective on how I think about math and made me realize that math is pretty abstract.” Another student wrote, “It activated a very engaged and synthesized way of thinking. once I drew one, I would draw more.” Two themes that emerged from “promoting community” were the “opportunity to express” and “seeing what others were thinking.” One student wrote, “Being able to share our ideas and visuals and having the opportunity to express where our heads were helped us understand each other and our community as a class.” Another student wrote, “Being able to share parts of our notebooks and seeing what others were thinking.”

Summary

Possibility books were implemented in a STEM methods course for future teachers, most of whom were not majoring in STEM. This was part of a larger project for undergraduate students in courses across multiple disciplines. The project aimed to determine if the cognitive theory of multimedia learning could be situated in social justice pedagogy to create a safe space for learning. Results proved promising, providing an index of scaled variables that could be tested further in courses that span STEM disciplines. Future research on how Possibility Books are instructionally implemented to deepen meaningful learning further is the next step in this project.

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