Addressing Equity and Identity in a General Education Mathematics Course

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Motivated by the goal of reducing equity gaps in achievement at a predominately white, public land grant research university, a team of mathematicians designed and implemented research-based strategies for promoting equitable instruction in a coordinated multi-section general education terminal mathematics course. To assess the impact of the course on students' mathematics identity, we utilized a pre- and post-survey adapted from an instrument developed by Hazari et al. (2020) which included scales to measure the constructs of sense of belonging, interest, recognition, and utility/competence. Preliminary analysis revealed that the means of student responses changed in the desired direction from pre- to post-test, with sense of belonging showing the greatest, statistically significant change. Initial quantitative and qualitative findings suggest the instruction tasks described here, which are relatively simple and inexpensive to implement, can have a significant impact on improving mathematical identity for students in a general education mathematics course.

Keywords: mathematical identity, sense of belonging, general education mathematics

In recent years, STEM education research has focused on student identity and its impact on students in STEM courses (Tytler, 2014). Some researchers have broadly defined science identity as an individual's "understandings of self," the ways in which they "make sense of themselves" and how they perceive they are "made sense of by others" within the context of science (Kane, 2012, p. 458). This definition of identity was applied to students pursuing study in physics (Hazari, Cass, & Beattie, 2015; Hazari, Sadler, & Sonnert, 2013) using a framework developed by Carlone and Johnson (2007) that introduced three constructs of science identity. These three constructs formed the basis of a framework adapted for physics identity by Hazari et al. (2020), who also developed a fourth construct.

Additionally, efforts to promote equitable education and positive STEM identity are widespread, with stakeholders in STEM education offering workshops and programming to guide instructors wishing to implement equitable curriculum and teaching practices. Though examples are plentiful, one such program is The Inclusive STEM Teaching Project, sponsored by the National Science Foundation (NSF), Directorate for Education and Human Resources (EHR), and Division of Undergraduate Education (DUE), and developed by a team of faculty representing Boston University, Northwestern, University of Michigan – Ann Arbor, Des Moines Area Community College, The University of Utah, University of Wisconsin – Madison, and the University of Georgia. (https://www.inclusivestemteaching.org/) Having completed the program, one of the authors conducted focus groups of UNL students to analyze localized needs, and then chose and implemented changes to the curriculum and instructional tasks in the general education mathematics course, Contemporary Mathematics. The strategies involve (1) making visible the contributions of mathematicians from historically underrepresented minority groups in multiple ways (course workbook, Open Educational Resources (OER) course textbook, biography assignments, homework questions, in-class discussions), (2) connecting these contributions to content learned in class, and (3) reflecting on personal learning experiences in mathematics alongside the experiences of contemporary mathematicians via an extended writing assignment.

In this study, we utilize an adaptation of the instrument employed by Hazari et. al. (2020) to assess constructs of identity in the context of mathematics. In particular, we use a pre- and post-survey assessment of mathematical identity in a general education (terminal) undergraduate mathematics course in which concerted efforts to promote equitable instruction and positive STEM identity have been implemented.

Context and Curricular Changes at our Institution

In response to emphasis at University of Nebraska-Lincoln (UNL) on reducing equity gaps in achievement across the institution, UNL's Department of Mathematics made a commitment to implement changes designed to address these gaps. One such change was the widespread use of Open Educational Resources (OER) as textbooks and extended tutoring/support opportunities for equitable access to resources. However, curricular changes were also needed to successfully address achievement gaps. In preparation for determining appropriate changes, the department procured university funding to collect feedback from underrepresented minority (URM) students using focus groups to identify curricular and other barriers to students' success in Math 203. In addition to pedagogical and logistical changes, findings from the focus groups led to curricular revisions specifically designed to address issues of mathematical diversity and identity. Consequently, the curricular changes were intended to help all students (URM students in particular) see themselves as part of the culture of mathematics, as individuals capable of mathematical success, and as being potential contributors to a body of mathematical knowledge fundamental to modern society. This was accomplished by including new or enhanced emphasis on topics for which relevant mathematics is being developed by researchers from URM groups (e.g., mathematical modeling, epidemiology, gerrymandering) and were incorporated into the curriculum in a multi-pronged approach:

1. Relevant content was added to the OER.
2. Each unit of the OER closes with a section featuring the mathematicians from URM groups whose research relates to these topics, featuring images (for quick, visual recognition of diversity), basic biographical data and links for further information.
3. Questions about a subset of the featured mathematicians are included in homework (WeBWorK) assigned for that unit based on these entries.
4. Students are tasked with selecting one of the mathematicians and writing a brief biography following specified prompts.
5. Instructors lead a brief in-class discussion about the mathematicians featured in students' biographies.
6. An extended biography and personal reflection is assigned directing students to the MAA publication "Living Proof" (Heinrich et al., 2019).

Methods

At the beginning of the spring semester of 2024, a pre-survey was administered as part of an assignment to all students enrolled in six different sections of Contemporary Mathematics, UNL's general education mathematics course for non-STEM related majors. Of these, 118 completed the survey expressing a willingness to be part of the study. To accommodate UNL's final week policy, the post-survey was administered as an extra credit assignment and was completed by 84 students at the close of the term. For the purposes of this study, the students are categorized as 78% majority (predominantly white students) and 22% non-majority (students from underrepresented minorities).

The survey instrument is based on one developed by Hazari, et al. (2020) that measures four constructs (interest, recognition, performance/competence, sense of belonging) determined to comprise physics identity in the context of undergraduates studying physics both at the beginning and near the end of their degree programs. We utilized similar questions by replacing references to "physics" with "math" when it made sense to do so and making a few other adjustments to better reflect course content and goals. We also added questions about growth mindset structured in a manner similar to those in the instrument used by Hazari, et al. (2020). A five-point Likert scale was used for responses to the construct items; four free response items were included for justifying a few key Likert ratings and to share comments directly correlated to the new curricular tasks addressing diversity and identity as explained above.

Indicator questions related to students' sense of belonging are shown in Table 1 below, both as an example and to highlight certain significant gains.

Table 1. Belonging Indicators [scale 1=not at all, 3=neutral, 5=very much so]

With respect to other students taking [____], to what extent do you…	[Math 203]	[other math classes]
…feel different from others in the community?	Q1	Q4
…feel alone or isolated?	Q2	Q5
…feel inadequate as a member?	Q3	Q6

Means from the Likert scale responses were analyzed and are summarized in the quantitative findings below. The free response survey questions on the post-test were categorized as positive, negative, or neutral responses by the authors and summarized in the qualitative findings.

Preliminary Quantitative Findings

A two-tailed z-Test in Excel was used to compare pre- to post-means, with α=0.05. Results show means of all individual questions and the combined categories changed in the desired direction from pre- to post-test, with an increased sense of belonging showing the greatest, statistically significant change. (See Table 2.)

Table 2. Pre/post mean comparisons for construct categories

Construct category	Pre-survey Mean (n=118)	Post-survey Mean (n=84)	Difference in Means	p-value (z-Test)
Interest	2.11	2.20	0.09	0.33
Recognition	3.26	3.36	0.10	0.16
Belonging [#]	3.77	2.03	-1.74	0
Growth Mindset [#]	3.28	2.99	-0.29	0.0001
Utility/Competence	3.46	3.62	0.16	0.024
Mathematical Identity	2.88	3.05	0.17	0.057

#The desired change based on the phrasing of questions in the Belonging and Growth Mindset categories is a decrease from pre- to post-means. For all other categories, the desired change is an increase.

A closer look at some individual indicators of construct categories for which combined mean changes were not statistically significant reveals some indicators exhibited greater change than others within their respective categories. Switching to a one-tailed z-Test (based on evidence from Table 2), Table 3 shows the results for two such indicators. Using the same Likert scale explained in Table 1, the desired change is positive.

Table 3. Pre/post mean comparisons for two isolated construct indicators

Construct Category and Indicator Item	Difference in Means	*p*-value
Recognition Q3: To what extent do you believe you have the ability to understand mathematics topics/concepts well?	0.275	0.026
Identity Q3: With respect to one or more of your identities, to what extent do you believe you or people like you can excel in mathematics?	0.22	0.059

Preliminary Qualitative Findings

Here are the three of the optional free response questions with a summary:

Q32: "With respect to one or more of your identities, to what extent do you believe that people like you can excel or are excelling in mathematics?" We categorized 41 of the 58 written responses as positive, nine neutral, and four negative. Additionally, we found responses that we couldn't categorize, due to poor wording or statements like "I don't understand the question." From the 41 positive responses, many students revealed a belief that if someone works hard, they can excel independent of their identity. The positive responses included:

- I think people like me, those who struggle can either do great or not. It all depends on their mindset and work ethic. If they go and continually ask for help and make an effort to understand the material, then they can be really successful.
- I have seen examples of LGBTQ+ people and females excelling in mathematics, especially in this course. I feel that people like me can excel in mathematics if they would like to. I'm glad that there are many different types of people represented in this course and not just old dead white guys.
- I think through my own identity, as a Hispanic female, there is potential for other women like me to excel in mathematics or who are currently excelling in mathematics that influence many others to do the same.

Q33 on the post-survey asked about key takeaways from the assignments related to the biographies of URM mathematicians. 56 of 64 responses were positive, responding that they learned about a wide variety of math careers, or saw a wide variety of identities represented, or they learned that even mathematicians struggle with math. One such response was,

- A big take away from me is that these people are normal people. Some of them did struggle in math in their lives. Not only that but they come from a number of backgrounds, some very similar to mine.

Q34: "If you indicated math will be useful to you in your future career, how do you see yourself using it? If you do not believe math will be useful for your career, can you see yourself using it in daily life? If so, how?" For this question, there were 62 responses. We categorized 59 of the 62 as positive responses, two neutral and one negative. This was an encouraging result, especially since many of those who chose to respond identified themselves as future teachers.

Results from these questions suggest positive outcomes, just as we saw in the quantitative data. The written responses from students identifying themselves as future teachers suggest we should implement instructional tasks and curriculum changes such as these in courses for future teachers.

Continued Analysis and Conclusions

Our initial statistical analysis compared means from the pooled responses for pre- and post-tests. However, the pre- and post-data can be paired, allowing additional analysis that can potentially address changes in identity at the individual level. Students can be isolated by demographics (gender, race, ethnicity, first-generation) to measure the impact on mathematical identity among these groups (the students we endeavored to reach). Another group of interest are those in the course pursuing a degree in elementary education, as most of these students take this course to fulfill a general education requirement. Improving sense of mathematical identity for future elementary teachers has significant potential to impact future learners of mathematics.

Findings from Hazari et. al. (2020) reveal that while all constructs from their study contribute to a positive physics identity, the impact of each construct is case-dependent. In particular, for undergraduate students at the beginning of their program of study, a strong sense of belonging has the strongest impact on their development of positive physics identity. While Math 203 is a general education course, it is not unreasonable to suggest results similar to those observed in this study (i.e., the strong gains in sense of belonging) have the potential to impact other undergraduate mathematics courses, particularly those at entry-level.

Implications of both quantitative and qualitative results from this study suggest tasks such as those described here, which are relatively simple and inexpensive to implement, can have a significant impact on improving students' mathematical identity for students with or without majors requiring courses in STEM.

Questions for Discussion: (a) How can we tell if we are impacting minority students when our population includes so few of them? (b) What are suggestions for analyzing the data without being affected by our own biases? (c) One goal is to analyze responses from those students going into (elementary) education. Can these curricular strategies and instructional tasks be used as recruiting tools for non-majority students to pursue teacher education? Will the positive changes in math identity among preservice teachers carry over into their practice and to their future students?

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