Use of WeBWorK as an Online Homework System as it Relates to Student Mathematical Identity

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This study explores how WeBWorK, an online homework system, influences student mathematical identity, with a special focus on students at a Native American-serving institution. Mathematical identity refers to beliefs, attitudes, and emotions toward mathematics, impacting motivation and learning. Through an online survey we gathered insight on student perceptions of WeBWorK's role in shaping four identity dimensions: self-efficacy, understanding, confidence, and persistence. Results reveal significant differences in student perceptions compared to prior studies, with survey participants showing lower engagement across these dimensions. Preliminary analysis suggests that WeBWorK may not equally support the mathematical identities of all students, particularly those from minority or first-generation backgrounds. This research contributes to understanding how web-based homework systems affect diverse student populations, providing insights for improving such systems to foster mathematical engagement and identity development.

Keywords: WeBWorK, online homework, mathematical identity

Introduction

In an increasingly technology-heavy world, many institutions of higher education are turning to the use of web-based homework (WBH) to allow for more time to be spent on material outside of class, which may be correlated to increases in student achievement (Cooper et al., 2006**;** Kehoe, 2010). Several types of WBH platforms exist and are used nationwide to supplement or replace traditional homework systems (Kehoe, 2010), including the open-source platform WeBWorK. From the perspective of the instructor, WBH has clear educational benefits, ranging from instantaneous feedback on assignments, an increase in understanding of the material, more consistent time spent studying, and leveling access across general and diverse populations of students (Boudreaux et al., 2022), as well as the economic benefit and objective nature of the system for large class sizes (Wood & Bhute, 2019). Furthermore, use of WBH allows additional time for students to develop a sense of their mathematical identity (Fernandez et al., 2024).

Mathematical identity here refers to a person's beliefs, attitudes, emotions, and dispositions about mathematics and their resulting motivation and approach to learning and using mathematics knowledge (Fernandez et al., 2024; Martin, 2000). There are a myriad of recent studies focused on how WBH affects mathematical identity in STEM minority populations (e.g., girls and women [Fernandez et al., 2024] and race [Nguyen et al., 2006]). Our study contributes to this important effort by looking at how the use of a particular WBH, WeBWorK, affects aspects of students' mathematical identity sorted by demographics including race (with a particular focus on Native American/Alaska Native students) and first-generation status. Our research question is: *How do student perceptions of their engagement with WeBWorK relate to different attributes of their mathematical identity? Moreover, how do these perceptions change with differing student demographics?*

Background

Student interaction with WBH systems has increased and has been particularly well-documented in the past 10 years (Dorko, 2020; Dorko et al., 2023; Hauk & Segalla, 2019; Kehoe, 2010; Serhan, 2019; Valdez & Maderal, 2021). Hauk & Segalla (2005) acknowledge WBH is "only a support tool…and [replaces] the unevenly implemented pedagogical interaction of homework grading with a uniform method of feedback" (p. 233). However, WBH systems are suggested to be at least as effective, if not more effective, than traditional written homework (Boudreaux et al., 2022; Hauk & Segalla, 2005; Wood & Bhute, 2019). Student perceptions of the value of WBH relate to a more positive learning experience in the classroom (Serhan, 2019). Furthermore, perception of the use of WBH is significantly correlated to motivation toward mathematical learning (Valdez & Maderal, 2021). Here, mathematical learning can be placed within the larger context of mathematical identity.

Considering attitudes toward aspects of WBH under the lens of mathematical identity can help us understand how a student may develop individual and group membership within a mathematical community (Cribbs et al., 2015). Mathematical identity is often used as a means for understanding student engagement with the subject (Black et al., 2010). This engagement often translates to growth of a student's conception of self, which has been found to be connected to their choice-making and performance at advanced levels (Mendick, 2006). Some researchers even claim that identity is crucial to the belief that one can be a creative participant in mathematics as a social practice (Boaler & Greeno, 2000).

For our study we will consider four facets of mathematical identity: self-efficacy, learning/understanding, confidence, and persistence. In particular, self-efficacy through a mathematical identity lens refers to a person's internal beliefs about their capabilities to produce levels of performance that allow them to exercise influence over events that affect their lives (Brenner et al., 2017) and their success in a mathematics classroom. Here, we ask how student engagement with WeBWorK relates to different aspects of a student's mathematical identity. As such we are interested in how these aspects relate across demographic axes such as first-generation and minority (with a specific focus on Native American/Alaska Native students) statuses.

Methods

For this study we administered an online survey to students at a public bachelors granting Native American-serving nontribal institution which we've given the pseudonym, Mountain College. The survey focused on student engagement with the web-based homework platform WeBWorK. WeBWorK is an open-source homework system supported by the Mathematical Association of America and the National Science Foundation. Created in 1996, WeBWorK describes itself as an open-source online homework system for STEM courses with an Open Problem Library of over 35,000 homework problems (WeBWorK, n.d.). At the time of the survey, WeBWorK was being used in all math classes at Mountain College from College Algebra, through the calculus sequence, and beyond in courses such as linear algebra and differential equations. WeBWorK had also been used for a number of previous terms.

Mountain College is located in the Southwestern United States serving a diverse student population. The majority of the student body identify in a minority race category (54%), with 27% of the total population as Native American or Alaska Native students. There is also a high percentage of first-generation college students (44%).

Overall the survey consisted of twenty five 5-scale Likert questions and five open responses covering four domains: accessibility, attitudes and engagement, mathematical identity, and

community. For this preliminary report, we will be focusing on the results pertaining to mathematical identity. There were six survey questions aimed at student engagement with WeBWorK and mathematical identity which can be seen in Table 1 below. All questions were asked on a 5-point Likert scale from 1-Strongly Agree to 5-Strongly Disagree. Whenever possible the wording of the questions matched questions used in previous investigations reported in the literature. These questions are identified in Table 1.

Table 1. Survey questions relating WeBWorK to students' mathematical identity

	Survey Question	Dimension of Identity
Q1	Given any WeBWorK problem I could start to answer it, or at least part of it, right away.	Self-efficacy
Q2[a]	Doing my homework using WeBWorK enhanced my learning of mathematics.	Learning/Understanding
Q3	Using WeBWorK has helped me understand material in other courses.	Learning/Understanding
Q4[a]	The use of WeBWorK has helped me develop confidence in doing mathematics.	Confidence
Q5[a]	Solving questions using WeBWorK prepared me for the paper-based class exams in the class.	Confidence
Q6	Doing homework using WeBWorK discouraged me to take more math classes.	Persistence

[a] (Serhan, 2019)

The survey was administered in Spring of 2024 inviting all Mountain College students with experience with WeBWorK at Mountain College to participate. In total we received 109 responses, 97 of which responded to all six of the identity questions. These 97 responses will be analyzed using primarily quantitative methods, specifically through a series of t-tests. Quantitative analysis will include descriptive statistics, comparing our means to results in existing literature, comparing means of individual questions sorted by various demographics, and exploring the correlation within and between the identity-focused questions and other dimensions captured by the survey.

Results

Of the 97 complete responses, 55% of students identified as a minority with 32% identifying as Native American/Alaska Native. Furthermore, nearly 31% (30.9) of the respondents identified as first-generation college students. Therefore, we can say the demographics of our survey participants are representative of the demographics of the student body of Mountain College.

Mountain College Compared to Previous Findings

Comparing the survey results from Mountain College to preexisting results found in literature yielded significant findings. Half of the questions focused on identity were taken from previous studies and their results are listed in Table 2 below.

Table 2. Means for survey questions relating WeBWorK to student mathematical identity

	Survey Question	Previous Findings	Survey Results
Q1	Given any WeBWorK problem I could start to answer it, or at least part of it, right away.	*N/A*	2.3
Q2	Doing my homework using WeBWorK enhanced my learning of mathematics.	*2.4*[a]	2.8**
Q3	Using WeBWorK has helped me understand material in other courses.	*N/A*	3.6
Q4	The use of WeBWorK has helped me develop confidence in doing mathematics.	*2.4*[a]	3.1**
Q5	Solving questions using WeBWorK prepared me for the paper-based class exams in the class.	*2.3*[a]	3.2**
Q6	Doing homework using WeBWorK discouraged me to take more math classes.	*N/A*	2.8

[a](Sehran, 2019) Note: Literature results were recalibrated to accommodate for a reverse-scoring Likert scale
** indicates a p-value less than 0.001

Every question that had a previously reported mean was found to be statistically significant compared to previous findings. For each of the questions a one-sample t-test was run using the mean from the literature. Our analysis found statistical evidence that Mountain College students' average scores not only differed from the previously reported average scores but were lower than all the previous findings. Note that since the Likert scales were presented with 1-Strongly Agree and 5-Strongly Disagree, a higher mean value indicates stronger disagreement with the question statement. A series of one sample t-tests with alpha = 0.05, two-tailed, were used and each difference of means was found to be statistically significant yielding $p<0.001$. These results suggest that at Mountain College WeBWorK may be supporting students' mathematical identity less than at other institutions.

Mountain College Findings by Demographic Group

Table 3 contains results from our survey data. Participant self-reported race is separated into three categories: white, non-minority identifying (White), n = 45; Native American/Alaska Native (NA/AN), n = 31; and non-NA/AN minority (Other), n = 16. Non-responses to the race demographic question (n = 5) were not included in the table or analysis. First-generation status is separated into two categories: (Yes), n = 30; and (No), n = 65. Non-responses to the first-generation demographic question (n = 2) are not included in the table or analysis.

Table 3. Results for survey questions broken out by student demographics

Survey Means by Demographic Groups					
Survey Question	Overall Mean	Race		First-Generation	
Question 1	2.2	White	2.2	Yes	2.2
		NA/AN	2.2	No	2.4
		Other	2.5		
Question 2	2.8	White	2.8	Yes	2.9
		NA/AN	2.7	No	2.8
		Other	2.6		
Question 3	3.6	White	3.6	Yes	3.5
		NA/AN	3.5	No	3.6
		Other	3.4		
Question 4	3.1	White	3.1	Yes	3.1
		NA/AN	3.1	No	3.2
		Other	3.0		
Question 5	3.2	White	3.1	Yes	3.3
		NA/AN	3.2	No	3.2
		Other	3.1		
Question 6	2.8	White	2.9	Yes	2.7
		NA/AN	2.8	No	2.9
		Other	3.1		

A preliminary series of one-way ANOVA tests have been run to explore differences within question responses between demographic groups within questions and thus far no statistical differences have been found. Furthermore, the p-values related to race ranged from 0.323 to 0.785 whereas the p-values related to first generation status ranged from 0.259 to 0.936.

In the presentation we will continue reporting on our analysis including a conversation focused on the correlation between the identity questions and also how the responses to the identity questions correlated with the other dimensions captured in the survey.

Discussion and Implications

In our preliminary analysis, we are noticing that while student responses at Mountain College are statistically different from previous studies, there is very little difference in survey responses based on categories within and across race and first-generation status. This invites questions about considering the data through a different lens. As such, we are considering analyzing the survey results through breaking down responses into cohorts based on both the types of classes taken and initial mathematics course placement. Furthermore, we ask how this free resource might work for development of student mathematical identity.

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