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A QUANTITATIVE ANALYSIS OF SIX ASPECTS OF STUDENT IDENTITY AND CREATIVITY-FOSTERING INSTRUCTION

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Can fostering mathematical creativity explicitly in a calculus I course impact students' mathematical identity? As a part of a larger research project exploring this question, a quantitative research study was developed to explore six aspects of student mathematical identity along with student perception of creativity-fostering instructor behavior. Analysis of pre- and post-semester survey data indicated that the instruments measuring aspects of student identity had strong reliability and good structure validity. Correlational analysis of the six aspects of student identity provided evidence that students' views of mathematics as a creative endeavor impacted the formation of self-efficacy in mathematics. The instrument measuring creativity-fostering instruction demonstrated low reliability and internal inconsistencies. Methodological issues related to measuring creativity-fostering instruction and directions for future research studying creativity-fostering and student identity are discussed.

LITERATURE REVIEW

Grootenboer and Marshman (2016) introduced the concept of mathematical identity as "a term to include affective, cognitive, and conative aspects" (p. 13) of the self. In particular, Gootenboer and Marshman (2016) considered aspects of affective domain of student learning, defined by McLeod (1992) as the "wide range of beliefs, feelings, and moods that are beyond the domain of cognition." At the same time, we recognize the interrelated nature of affect and cognition. Schoenfeld (2013) asserts that "one major component of mathematical competence consists of being able to use the resources at one's disposal with some degree of efficiency when working somewhat unfamiliar problems" (p. 363). Such ability is very closely related to one's beliefs about their ability and participation in mathematics, as well as fundamental beliefs about the nature of mathematics. Thus, studying affect as part of students' mathematical identity serves important role in the research of mathematics education.

Mathematical identity has been characterized as a dynamic construct, one that is continually constructed and reconstructed over time (Fellus, 2019). Changes in student identity are potentially occurring continually as a result of student's classroom experience. However, Grootenboer and Marshman (2016) stated that there is a "lack of clarity about…the development of beliefs and attitudes about mathematics in the classroom" (p. 23). This study examines student emotions, attitudes, and beliefs regarding mathematics, as well as *self-efficacy for problem solving*, or beliefs in one's confidence for solving mathematical problems (Bandura, 1997), and *creative self-efficacy for mathematics*, or beliefs in one's ability to produce creative mathematical outcomes (influenced by Tierney & Farmer, 2002). Additionally, we investigated three of nine aspects of creativity-fostering teaching based on Cropley (2018), selected due to of our interest in their relation to mathematical problem solving and their potential impact on identity. These aspects were *flexibility*, encouraging "flexible thinking in students;" *evaluation*, promoting "self-evaluation in students;" and *frustration*, helping "students learn to cope with frustration and failure" (Cropley, 2018; p. 5).

METHODS

Data was collected in three Calculus I classrooms in two universities in the south mid-west United States. This survey was given as part of a larger study to investigate how fostering creativity can impact students' mathematical identities. 38 students participated in the beginning-of-semester survey and 30 in the end of semester, with 25 completing both.

Student surveys included three instruments. The first measured affect using 12 items designed to measure positive emotion toward mathematics (emotion), attitudes concerning mathematics as important (importance), and beliefs concerning mathematics as a creative endeavor (creativity). The second consisted of 18 items measuring beliefs related to students' self-efficacy for problem solving (SEPS), creative self-efficacy for mathematics (CSEM), and ways students perceived themselves gaining self-efficacy toward mathematics, i.e. the sources of self-efficacy (SSE) related to the class. The SEPS consisted of 6 items measuring beliefs in students' confidence in ability to solve algebra, trigonometry, and calculus problems. The CSEM consisted of 4 items measuring self-efficacy related to originality, fluency, flexibility (Torrance, 1974), and collaboration in developing mathematical ideas (Tierney & Famer, 2002). Both the SEPS and CSEM were constructed following Bandura's (2006) guide for constructing scales using 11-point 0-100% confidence ratings. The SSE consisted of 8 items based of Bandura's (1997) four sources of self-efficacy using a Likert scale (Strongly agree to strongly disagree) on statements of the form "I gained confidence in this course from…". These first two instruments were administered at the beginning and end of the semester.

The third instrument was constructed by adopting three subscales (flexibility, evaluation, and frustration) from Soh's (2015) Creativity-Facilitating Teaching Index (CFTIndex), an instructor self-report instrument measuring nine aspects of general creativity-facilitating teaching (CFT; Cropley 2018) not specific to mathematics. Each subscale had five items which were re-writen from the students' perspective and worded past-tense with minor changes to increase readability. This instrument was administered at the end of semester with the prompt, "Please rate how often did your instructor do each of the following (0-100% of the time)" with items such as "When we experienced failure, our instructor helped us look for other possible solutions."

Reliability tests were conducted, and two models were run for each of the above three instruments: item response theory (IRT) models and confirmatory factor analysis (CFA) models using the polychoric correlation matrix. Based on these models, beginning- and end-of-semester changes of student ratings and estimates of the correlations between the factors were considered.

RESULTS

The items measuring CSEM, SSE, SEPS, emotion, and importance each showed high reliability (α ranging from 0.84 to 0.86; $\alpha \geq 0.8$ is good), with the items for creativity showing lower reliability (α=0.67). For each of the first two instruments, the IRT model fit was very poor compared to the CFA with correlated factors (RMSA = 0.044 for attitudes/beliefs and RMSE = 0.017 for the two-factor

SEPS and CSEM model). The third instrument measuring CFT showed lower reliability than reported by Soh (2015) and very poor IRT model fit. There was severe skew in the data with most students responding very highly on the scale. One CFTIndex items ("My instructor allowed us to show one another our work before submission.") was negatively correlated with the total scale. CFA was not possible with the CFTIndex due to the covariance matrix not being positive definite.

From the models studying emotions, attitudes, and beliefs, correlations within factors were calculated. Between models, point-estimates of factors were calculated for an initial estimate of correlations. Statistically significant ($p<0.05$) correlations between factors are shown below in Fig.1, with model correlations in black, and point-estimate correlations in grey.

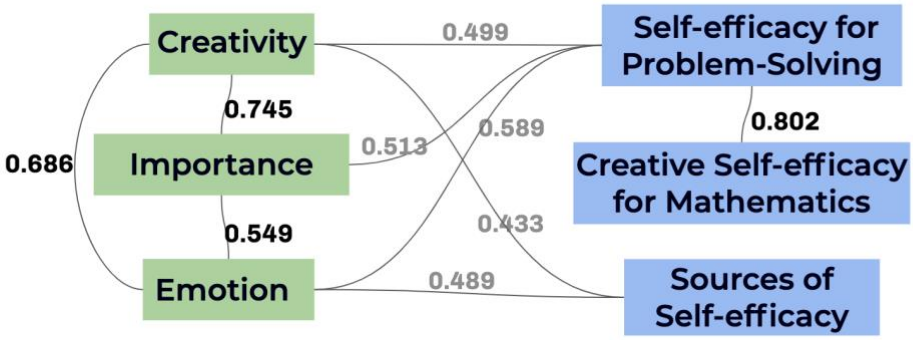

Figure 1: Correlations between six aspects of student affect/identity

Finally, using the data from the 25 students that took both beginning and end of semester surveys, a t-test of the above displayed factors was conducted giving evidence in a decrease in ratings of importance ($p=0.0001$), an increase in CSEM ($p=0.017$), and an increase in SEPS ($p=0.0823$). Affect and creativity showed no significant change.

DISCUSSION

Analysis of the self-efficacy instruments demonstrates both strong reliability and good model fit. Model correlation between SEPS and CSEM also gives evidence of convergent validity. Thus, we recommend further study using this instrument on larger and more diverse sample sizes. The correlation between SEPS and views of mathematics as creative and important, as well as positive emotion toward mathematics illustrates the potential role of self-efficacy in promoting positive attitudes, beliefs, and emotion toward mathematics.

The low reliability and poor model fit of the CFTIndex demonstrates that it may not be appropriate to adapt the CFTIndex as descried in this study. The skew in student responses may be an indication that the CFTIndex does not discriminate student perspectives of CFT well. These issues highlight a need for student instruments that can better distinguish specific teaching actions identified for fostering mathematical creativity. Currently, we are in the process of creating a new student instrument based on teacher actions for fostering mathematical creativity (Cilli-Turner et al., 2019).

The increase in student CSE for mathematics may be connected to the use of creativity-based tasks in the classroom. In giving students opportunity to experience their own creative accomplishments and observe one another's creativity, the use of creativity-based tasks in class may provide students greater opportunities for gaining self-efficacy from their own experiences and vicariously (Bandura, 1997). However, given our current sample size, more data and further analysis is needed. The decrease in student views of mathematics as important runs contrary to our hope that student experiencing mathematics as creative would view mathematics as more important. Following Fellus' (2019) conceptualization of identity, we can see a change like this potentially resulting from a process of reconceptualization of meaning and values related to mathematics; students may be grappling with multiple views of mathematics (procedural or conceptual, creative or non-creative), some of which diverge from previous experiences in mathematics. This needs further investigation.

Although the data analyzed in this study did not appear to violate assumptions of normality, we did not analyze the independence of CFT and affect variables across the different calculus classes from which the data was collected. To more effectively study the relationship between CFT and affect in multiple classrooms, we might need to account for intraclass correlation (Guo, 2004) since changes in student identity may be impacted by individual instructors. We plan to utilize hierarchical linear modeling (Guo, 2004) to study group-level (course) effects on similar aspects of student identity across multiple classrooms.

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