STUDENT-CENTERED INSTRUCTION AND ITS EFFECT ON MATHEMATICS ENGAGEMENT BY RACE

by

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This study aimed to improve knowledge about the efficacy of student-centered instruction in mathematics and specifically examine relevant racial differences in its efficacy. In particular, the study tested student-centered instruction's effects on four dimensions of mathematics engagement: behavioral, cognitive, emotional, and social. This was done using a multilevel path analysis that included a racial interaction variables as well as other control variables. The sample of the study was taken from Western Pennsylvania and is made up of 3883 6th through 12th graders. The study determined there was a positive relationship between student-centered instruction for all four measures of mathematics engagement. Black students appeared to benefit less from student-centered instruction than white students on all four measures of engagement, but those of low socioeconomic status seemed to benefit more from student-centered instruction on three of the dimensions. The implication that there is a racial difference in the effect of student-centered instruction should be investigated further.

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PREFACE

Thanks to my committee and everyone that made this possible.

1.0 INTRODUCTION

The academic achievement gap between black and white racial groups is a persistent problem that cannot be entirely accounted for by differences in wealth between racial groups (Magnuson & Duncan, 2005) or other demographic factors. Although gaps exist in many areas, one of the most noticeable is in mathematics. The National Assessment of Educational Progress (NAEP) conducted in 2011 revealed a 31-point gap between blacks and whites in a mathematics standardized test scored out of 500-- almost equivalent to the difference between the basic and proficient levels (Lbogle, 2015). Even more disturbing is the finding that this disparity seems to grow as education progresses (Bacharach, Baumeister, & Furr, 2003) and presents a major obstacle to minorities' ability to access the career types that require high academic achievement in mathematics, effectively inhibiting them from entering most STEM disciplines.

The idea that student-centered instruction is one way to improve engagement and close the racial achievement gap has precipitated a shift to student-centered instruction in mathematics, in which instruction focuses on students' active participation (Newble & Cannon, 2000). However, little research has focused on student-centered instruction's effects on engagement in mathematics. This means that the exact dynamics of student-centered instruction's effects are unknown and could vary by demographic characteristics. For example, African-Americans might differ in how they experience or participate in student-centered mathematics instruction from their white peers. For some African-American students, student-centered mathematics instruction could engender a feeling of empowerment that reduces the racial stereotype threat –an activation of negative stereotypes shown to have a detrimental effect on academic performance (Steele, 1997). Such empowerment, in turn, could lead them to engage more in instruction. Conversely, student-centered instruction's focus on the student could amplify stereotype threat, which could contribute to African American students engaging less to avoid conforming to the stereotype.

Any effect should be pronounced in mathematics not only because it is a subject in which engagement tends to decrease over time (Marks, 2000) but also because it is a field in which there are negative stereotypes about minorities (Nguyen & Ryan, 2008). Moreover, it should affect primarily emotional engagement because the control of negative emotions has been shown to be crucial to stereotype threat (Johns, Inzlicht, & Schmader, 2008).

This is important, in general, because the concept of engagement is central to many theories on why some learners learn more than others, and it is key for African-Americans because of the engagement-achievement paradox, where minorities typically have as high or higher engagement than whites but have significantly lower academic achievement (Shernoff & Schmidt, 2008).

Accordingly, this study aims to examine the effect of student-centered mathematics instruction on behavioral, emotional, cognitive, and social engagement in mathematics coursework and whether this relationship is affected by being an African-American. It seeks to lay the groundwork for evaluating student-centered instruction as a tool to increase mathematics engagement and for establishing a context for its role in methods to improve racial equity in mathematics.

1.1 STUDENT_CENTERED INSTRUCTION

Drawing from constructivist theory, student-centered instruction is a form of teaching based on conceptual understanding and incremental growth through discourse, collaboration, and honoring and respecting students' voices (Meece, 2003). It is explicitly focused on the student and shifts intellectual authority back to them (Felder & Brent, 1996). When college students were exposed to this type of instruction, they asked more questions, shared more information, and generated more ideas compared with students taught using more traditional methods (Greeson, 1988). In general, student-centered instruction is focused on improving student's competence, autonomy, and relatedness to others in line with the APA's learner centered principles (Workgroup, 1997).

In contrast, teacher-centered instruction is focused on the teacher (Loyens & Rikers, 2011) and on the teacher's authority. In this style, the teacher typically talks or lectures to students (Cuban, 2006), the emphasis is on the rote memorization of procedures rather than conceptual understanding (Stein, Kinder, Silbert, & Carnine, 2005), and little time is allotted for activities that validate students, such as opinion sharing or reflecting on what they are learning (Cuban, 1984).

Student-centered instruction is preferred by students (Lea, Stephenson, & Troy, 2003), including student teachers (Baeten, Dochy, Struyven, Parmentier, & Vanderbruggen, 2016), and has shown to improve students' motivation to learn when introduced slowly (Baeten, Dochy, & Struyven, 2013). Although many of its characteristics are aimed at improving the dimensions of students' engagement, this mechanism has not been fully explored either with regard to mathematics or even more specifically with regard to racial group learning. Some evidence indicates that the implementation of student-centered mathematics instruction reduces the racial achievement gap (Jamar & Pitts, 2005; Salinas & Garr, 2009), but the evidence has problems with endogeneity or is anecdotal. One study examined the "best practices" of only one mathematics teacher (Jamar & Pitts, 2005). The other study looked at student-centered instruction only at the school-level, not at the classroom- or teacher-levels (Salinas & Garr, 2009).

Because many policies have been enacted by local and state agencies to reform mathematics instruction in accordance with student-centered instruction's principles (Resnick, Stein, & Coon, 2008), it is important to examine student-centered instruction's implications. Any race-based differences are of particular interest given that by 2020 over half of the children in the United States will belong to a minority race or ethnic group (Colby & Ortman, 2015).

1.2 STEREOTYPE THREAT

Due to its foundations in constructivist learning theories, student-centered instruction may result in a greater improvement in students' cognitive, behavioral, and social engagement in mathematics class. However, evidence is mixed as to how student-centered mathematics instruction could shape minority students' emotional engagement. On the one hand, it could increase emotional engagement by buffering the perception or response to stereotype threat in math classrooms. Stereotype threat refers to the anxiety minorities have about being judged against negative stereotypes, which in turn results in reduced performance (Steele, 1997). Because stereotype threat originates from the fear of fulfilling negative stereotypes, one way to successfully counter it is to provide other ways of self-affirming a positive academic self-image (Croizet, Désert, Dutrévis, & Leyens, 2000). It has also been shown that feeling empowered reduces the effect of stereotype threat (Van Loo & Rydell, 2013). In effect, stereotype threat has been shown to trigger emotions that are detrimental to learning (Mangels, Good, Whiteman, Maniscalco, & Dweck, 2012). Minorities who experience stereotype threat tend to decrease their engagement with that subject area (Aronson, Fried, & Good, 2002), presumably as a psychological defense mechanism. With its focus on empowering students, student-centered mathematics instruction could possibly have an outsize effect on emotional engagement by reducing stereotype threat.

On the other hand, student-centered instruction requires students to participate more. This increased scrutiny might transform the classroom into a place where minorities feel they must perform well to avoid confirming negative stereotypes. This could result in emotional disengagement to avoid the negative emotions that increased stereotype threat would engender, such as anxiety and low self-esteem.

1.3 MATHEMATICS ENGAGEMENT

In this study, we focus on mathematics both because active engagement in mathematics coursework is essential to a career in STEM (National Science Foundation, 2016), and because engagement in this area tends to decline over time (Marks, 2000), particularly for low-income and minority youth who struggle with disproportionate declines in mathematics engagement over their school careers (Martin, Way, Bobis, & Anderson, 2014).

Engagement, in the broader sense, is sometimes referred to as school or classroom engagement. It is a multi-dimensional construct (Fredricks, Blumenfeld, & Paris, 2004) with each dimension having a distinct character. There are four dimensions of engagement in mathematics coursework: behavioral, emotional, cognitive, and social (Wang, Fredricks, Ye, Hofkens, & Linn, 2016). Behavioral engagement in mathematics courses refers to involvement in academic and classroom activities and the presence of positive behavior (Fredricks et al., 2004). Emotional engagement refers to positive interactions with teachers, peers, and classroom activities as well as the student's emotional relationship with the learning material (Voelkl, 1997). Cognitive engagement denotes the student's self-regulated learning, use of deep learning strategies, and ability to use the appropriate strategies to comprehend complex ideas in a mathematics class (Zimmerman, 1990). Finally, social engagement in mathematics reflects the quality of a student's social relationships and their willingness to form and maintain relationships while learning (Wang et al., 2016).

Each dimension of engagement has been shown to have differing effects on achievement and other education outcomes. Behavioral engagement has been linked with increased mathematics achievement (Robinson & Mueller, 2014), decreased truancy (Virtanen, Lerkkanen, Poikkeus, & Kuorelahti, 2014), and reading achievement (Ponitz, Rimm-Kaufman, Grimm, & Curby, 2009). Emotional engagement has also been shown to positively affect mathematics (Sciarra & Seirup, 2008) and reading (Lee, 2014) achievement as well as decrease the risk of dropping out (Zablocki, 2010). Cognitive engagement, along with similar effects on mathematics achievement as behavioral engagement (Sciarra & Seirup, 2008), is also associated with decreased school stress and less cheating (Conner & Pope, 2013). Social engagement—a relatively new dimension—has fewer reports in the literature about its effects, but current studies suggest peer relations have an important role in academic achievement (Lynch, Lerner, & Leventhal, 2013). Thus, each dimension of mathematics engagement has an important role to play in the effective learning of mathematics.

1.4 LITERATURE GAPS

Most of the current literature on mathematics engagement has focused on the influence of the quality of teacher and parent support and interactions (Kelly & Zhang, 2016; Martin & Rimm-Kaufman, 2015; Rimm-Kaufman, Baroody, Larsen, Curby, & Abry, 2015; Robinson & Mueller, 2014) and the effect of mathematics engagement on education outcomes (Darensbourg & Blake, 2013; Galla et al., 2014; Rowan-Kenyon, Swan, & Creager, 2012). Relatively little research has concentrated on the relationship between students' race and their engagement in mathematics coursework (Darensbourg & Blake, 2013; Martinez & Guzman, 2013; Sciarra & Seirup, 2008) and even less research has been done on the effect of student-centered instruction on mathematics engagement. An exception is a study that demonstrated the potential of student-centered mathematics instruction to improve overall mathematics engagement (Gningue, Peach, & Schroder, 2013). Research is clearly lacking on both the effect of student-centered instruction on mathematics engagement and on whether the effect differs based on students' race. More research in this area will enable the adaptation of teaching practices to fit an increasingly diverse population, which in turn will help minorities reach their full potential and erase current disparities in achievement and representation in STEM fields.

1.5 CURRENT STUDY

This study assesses how student-centered instruction is associated with four dimensions of engagement in a sample of 3,883 adolescent students from a collection of middle and high schools in Western Pennsylvania during the fall 2014 semester. It also examines whether African-American status moderates the relationship between student-centered mathematics instruction with any of the engagement dimensions, in particular, emotional engagement, to evaluate student-centered instruction as a tool for closing the racial-achievement gap. The study results provide a more nuanced view of mathematics student-centered instruction, allowing additional study to evaluate if the experiences of minorities with this type of instruction need to be evaluated apart from the general population.

2.0 METHODS

2.1 RESEARCH QUESTIONS

1. What are the effects of student-centered mathematics instruction on students' cognitive, behavioral, emotional, and social engagement in mathematics?
2. Does student race moderate the effects of student-centered mathematics instruction on student's cognitive, behavioral, affective, or social engagement in mathematics, when evaluation considers students' socioeconomic status (SES) and gender?

2.2 HYPOTHESIS

1. Student-centered mathematics instruction will have a positive effect on students' cognitive, behavioral, emotional, and social engagement in mathematics.

2.3 PARTICIPANTS AND PROCEDURES

Our sample consisted of middle school and high school students recruited from six public school districts in Western Pennsylvania. The student sample included 3883 6th through 12th graders

(17.5%, 6th grade 18.8%, 7th grade, 19.4%, 8th grade, 12.9%, 9th grade, 10.9% 10th grade, 11.3%, 11th grade, and 9.2% 12th grade). The student sample was 52.1% female, 66.1% European American, 23.8% African American, 7.2% multiracial, and 2.9% Asian American. Approximately 38.2% of the student sample qualified for free or reduced-price lunch.

The sample was collected at every school by first describing the study to mathematics teachers and obtaining their consent to conduct the study in their classrooms. Students in those classes who agreed to participate in the study completed the computer-based survey during regular instruction time. No names were used and the results of the survey were confidential. Student demographic information was obtained through school records.

2.4 MEASURES

2.4.1 Demographics

All demographic variables were collected through student reports and then confirmed using school records. SES and gender were collected to use as control variables.

SES was operationalized as a dummy variable at the individual level based on whether the student was eligible for a free or reduced-price lunch.

Gender was represented as a dummy variable at the student level (1 = female).

Race was obtained by asking students if they identified as black or African American and separating those that did not identify as solely African-American or white, e.g., Asian. Those who did not identify as black or white were removed from the data set. Those who identified as African-American were coded as a 1 on a dummy variable.

2.4.2 Student-Centered Instruction

Student-centered instruction was assessed in the fall of the 2014 academic year by asking student's six items that described components of student-centered instruction, including a focus on conceptual understanding ("When I show my teacher an answer, he/she asks me to explain how I got that answer."), not providing feedback that reduces the cognitive demand of the task ("My teacher shows me how to solve problems by myself."), and supporting students' intellectual authority ("My teacher allows me to choose how to do my work in the classroom."). Item responses were on a 5-point Likert scale, ranging from 1 (*almost never* or *not true at all*) to 5 (*often* or *very often true*). Items were averaged, such that higher scores indicated greater use of student-centered instruction ($\alpha = .812$).

2.4.3 Engagement (Behavioral, Cognitive, Emotional, Social)

We use the student-report survey, mathematics, and science engagement scales, of behavioral, cognitive, emotional, and social mathematics engagement found in "The Mathematics and Science Engagement Scales: Scale Development, Validation, and Psychometric Properties" (Wang et. al.,2016).

Behavioral engagement was assessed in the fall of the academic year by asking students a set of eight items. The items dealt with both concrete physical behaviors ("I ask questions in mathematics class.") and more subjective mental behaviors ("I put effort into learning mathematics.") Item responses were on a 5-point Likert scale ranging from 1 (*not at all like me*) to 5 (*very much like me*). Items were averaged together, such that higher scores indicated greater behavioral engagement ($\alpha = .82$).

Cognitive engagement was assessed in the fall of the 2014 academic year by giving students a set of eight items. Items focused on the student's mental flexibility ("I think about different ways to solve a problem.") and effort made to think about problems ("I go through the work that I do for mathematics class and make sure that it's right."). Item responses were on a 5-point Likert scale, ranging from 1 (*not at all like me*) to 5 (*very much like me*). Items were averaged such that higher scores indicated greater cognitive engagement (α = .75).

Emotional engagement was assessed in the fall of the 2014 academic year by giving students a set of ten items that addressed both positive ("I feel good when I am in mathematics class.") and negative emotions ("I often feel frustrated in mathematics class.") about mathematics with negative feelings reverse coded. Item responses were on a 5-point Likert scale ranging from 1 (*not at all like me*) to 5 (*very much like me*). Items were averaged such that higher scores indicated greater emotional engagement (α = .89).

Social engagement was assessed in the fall of the 2014 academic year by giving students a set of seven items that focused on ability to learn from others ("I build on others' ideas.") and cooperation with classmates ("I try to work with others who can help me in mathematics."). Item responses were on a 5-point Likert scale, ranging from 1 (*not at all like me*) to 5 (*very much like me*). Items were averaged such that higher scores indicated greater emotional engagement (α = .89).

2.5 DATA ANALYTIC STRATEGY

The study used a hierarchal path analysis model employing Mplus, version 7.2 (Muthén & Muthén, 2012). Students who did not identify as solely as African-American or white were excluded from the analysis, which reduced the number of subjects to 3488. When the model was run the number of subjects dropped further to 2719 because of missing data. The missing data was assessed and a determination was made that it likely fulfills the missing-at-random (MAR) assumption. Notably, the missing data for student-centered instruction was less white and more black then the non-missing data. Maximum likelihood (ML) was used to estimate the data in the dependent variables because this method has proved robust even if the MAR assumption is violated. A hierarchal model was used to account for the violation of the assumption of independence expected from a collection of data about teaching practices in the same classrooms. Scored rather than latent constructs were used because of computational limits in Mplus with multiple interactions in a hierarchal model. Gender and SES were included in the model as control variables.

3.0 RESULTS

3.1 DESCRIPTIVE STATISTICS

After missing data was dropped descriptive statistics for the African-American and white groups were calculated and are presented in Table 1. The group of white students (N=2137) was considerably larger than the African-American group (N=582). The African-American group had lower engagement in all measures of engagement except for emotional engagement, in which they had slighter higher engagement. African-American students also had higher amounts of student-centered instruction.

3.2 PATH ANALYSIS MODEL

The model had the same number of parameters as the baseline model and so had zero degrees of freedom. Accordingly, no fit statistics were available. The paths from student-centered instruction to behavioral engagement, cognitive engagement, emotional engagement, and social engagement were significant at the p<.0001 level. All four dimensions of mathematics engagement behavioral (β=.37), cognitive (β=.33), emotional (β=.48), and social (β=.36) were positively predicted by student-centered instruction. There were also significant effects of being female, being African-American, and having a low SES (see Figure 1). There were significant negative interactions between being African-American and student-centered instruction in all four dimensions of mathematics engagement (see Figure 2). The strongest was on emotional, $\beta=-.49$, $p<.0001$, and behavioral engagement, $\beta=-.46$, $p<.0001$. However, cognitive, $\beta=-.35$, $p=.0004$, and social engagement, $\beta=-.31$, $p<.0001$, also had sizable effects. In contrast, interaction effects based on low SES were significant and positive for behavioral, emotional, and cognitive engagement and non-significant for social engagement.

4.0 DISCUSSION

The results of this study were greatly aided by the strength of the study sample. Even with large amounts of missing data there were still enough subjects of both races to retain power. Though only rudimentary the descriptive statistics suggest the main story of this study. Despite, higher amounts of student-centered instruction and a high percentage of low SES students that should benefit more from student-centered instruction African-Americans had lower amounts of engagement in three dimensions.

Overall, the study results confirmed the hypothesis that student-centered instruction would increase all four dimensions of engagement, validating student-centered mathematics instruction as a way to shape students' engagement in mathematics. This confirmation is important for the core rationale of shifting toward student-centered instruction in mathematics, especially since the results indicate a sizable effect across all four dimensions. However, since the study did not assess whether the increases in the dimensions of engagement lead to commensurate gains in achievement, it is not possible to fully support the proposed mechanism of student-centered instruction improving mathematics achievement. Despite this, the confirmation of the first part of the mechanism is an important step in verifying the effectiveness of student-centered instruction with the caveat it may be less effective for minority groups.

That was perhaps the most interesting finding. The presence of negative interactions between African-American identification and student-centered instruction. Although student-centered mathematics instruction had a positive effect, study results showed a highly significant negative interaction with African-American identity in all four engagement dimensions. This was surprising because while an interaction in mathematics emotional engagement was expected, in accordance with the study's stereotype threat frame, the strength and presence of a negative effect across all four dimensions was not theoretically predicted.

As the interaction figures shows this means that typically African-American students with lower amounts of student-centered instruction had higher or equivalent engagement than white students, but as the amount of student-centered instruction increased their white peers overtook them. The fact that the standardized coefficients of the interaction effects were sizable, on par with or bigger than the coefficient of student-centered instruction illustrates the problem. The interaction effect suggests that more student-centered instruction would result in an engagement gap between white and African-American students. Gaining a more detailed view of this effect would help evaluate what if anything about teaching practices could be implemented to counter this effect.

This especially necessary to do considering the other interaction effect the study revealed. That low SES also had a significant interaction but in the opposite direction for three of the engagement dimensions is significant because often racial problems can be attributed in part to socioeconomic class issues. The fact that this is not the case points to it being entirely a racial issue. It also means that use of student-centered instruction seems to be very mixed. While the analysis indicates it is less effective for African-Americans, many African-Americans in the sample and in general have a low SES. As the interaction figures show for three of the four types of engagement the SES interaction is enough to propel low SES students equal in engagement to their high SES peers. It would be very beneficial to keep the effectiveness of student-centered for those with low SES, but eliminate its inefficiency for African-American students.

As stated in the introduction, these differences can be viewed through the lens of stereotype threat, which is expected to be more pronounced for identities that are easily identifiable. For example, although poor students could conceivably hide their poverty, they would be hard-pressed to hide their race. Consequently, if a student is asked to give a presentation on math, race might be more salient than their low SES. However, to confirm this theory further research needs to be done. Ideally, such research would try to modify student-centered instruction to limit the effect of stereotype threat. Possible modifications could be an explicit emphasis on learning rather than on assessment or education about stereotype threat and the inaccuracy of stereotypes.

This study also confirmed the four engagement dimensions as independent theoretical constructs and determined the strength of student-centered instruction's effects, as well as the differential effect for African-American students, varies by engagement type. In particular, the differential effect for African-Americans of student-centered instruction was strongest for emotional engagement. This finding lends credence to the stereotype threat frame, as emotional engagement is expected to be particularly affected by stereotype threat.

Because of the complex nature of minorities' relationship with engagement and achievement, it is not possible to conclusively determine student-centered instruction's effect on the racial achievement gap. It would seem that student-centered instruction is less effective in improving engagement for African-Americans, but this does not necessarily translate into a corresponding effect on achievement.

4.1 LIMITATIONS AND FUTURE DIRECTIONS

The lack of a qualitative assessment limited the study's findings of what other practices might unintentionally be included in student-centered instruction. This limitation prevents a determination of what exactly is causing the differential effect of student-centered instruction by race. A mixed-model approach with classroom observers would help resolve this issue. The study also took place in the Greater Pittsburgh Area, which could limit the ability to generalize results. A nationally representative study would remove this limitation. This study was also cross-sectional, curtailing our ability to draw causal conclusions between student-centered instruction and the dimensions of mathematics engagement. A longitudinal study would need to be done to draw causal connections.

APPENDIX A

TABLES

Table 1: Descriptive Statistics for the Sample Divided by Race (N=2719)

	Race							
	African-American				White			
	Mean/ Proportion	SD	Min	Max	Mean/ Proportion	SD	Min	Max
SES (Low)	84.70%				16.60%			
Gender (Female)	51.80%				50.30%			
SCI	3.84	0.69	1.00	5.00	3.76	0.65	1.00	5.00
Behavioral Engagement	3.69	0.51	1.00	5.00	3.94	0.47	1.13	5.00
Cognitive Engagement	3.68	0.51	1.25	5.00	3.80	0.43	1.13	5.00
Emotional Engagement	3.69	0.73	1.00	5.00	3.67	0.83	1.00	5.00
Social Engagement	3.71	0.53	1.43	5.00	3.81	0.46	1.00	5.00

Note: African-American group (n=582) White group (n=2137)

APPENDIX B

FIGURES

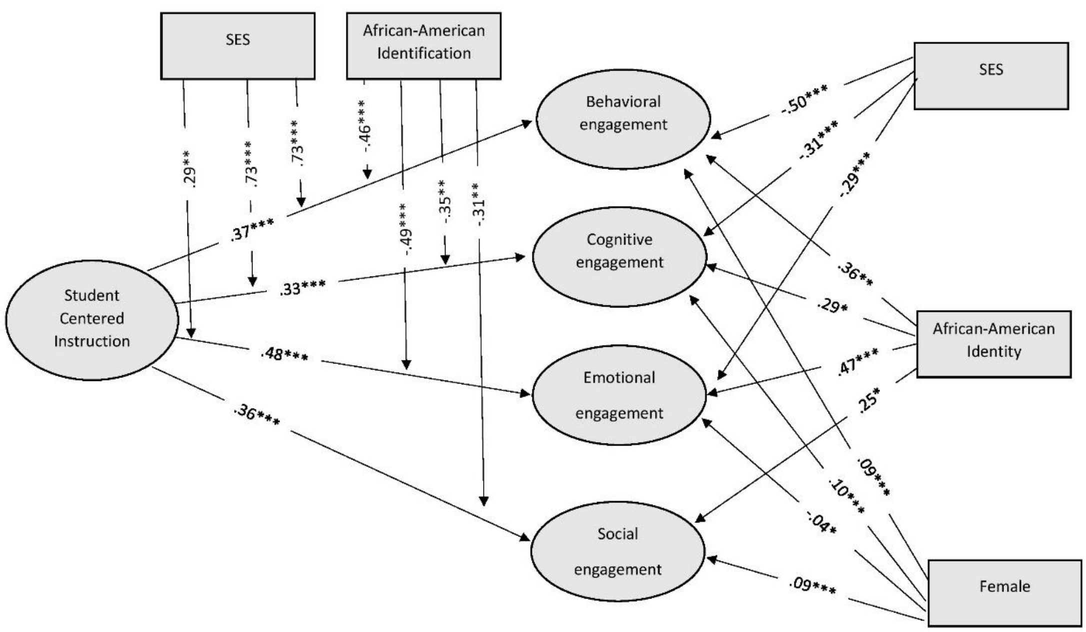

Figure 1: Path model diagram with standardized coefficients.

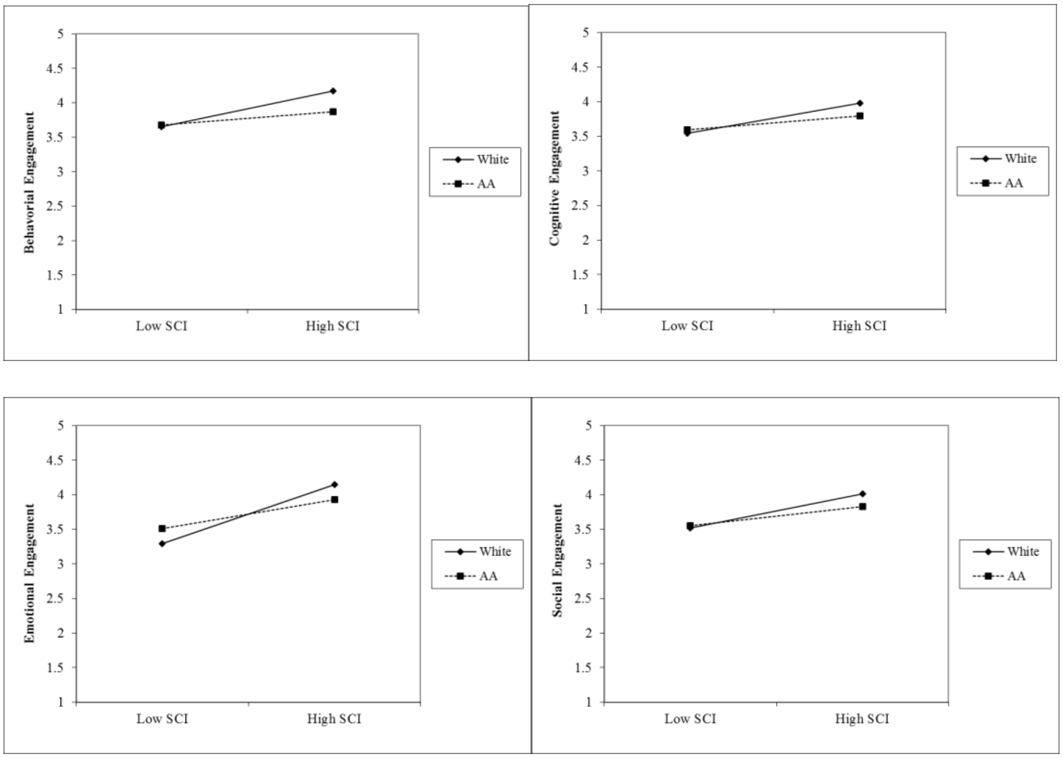

Figure 2: Race interaction effects on the types of engagement with low and high one standard deviation from the mean.

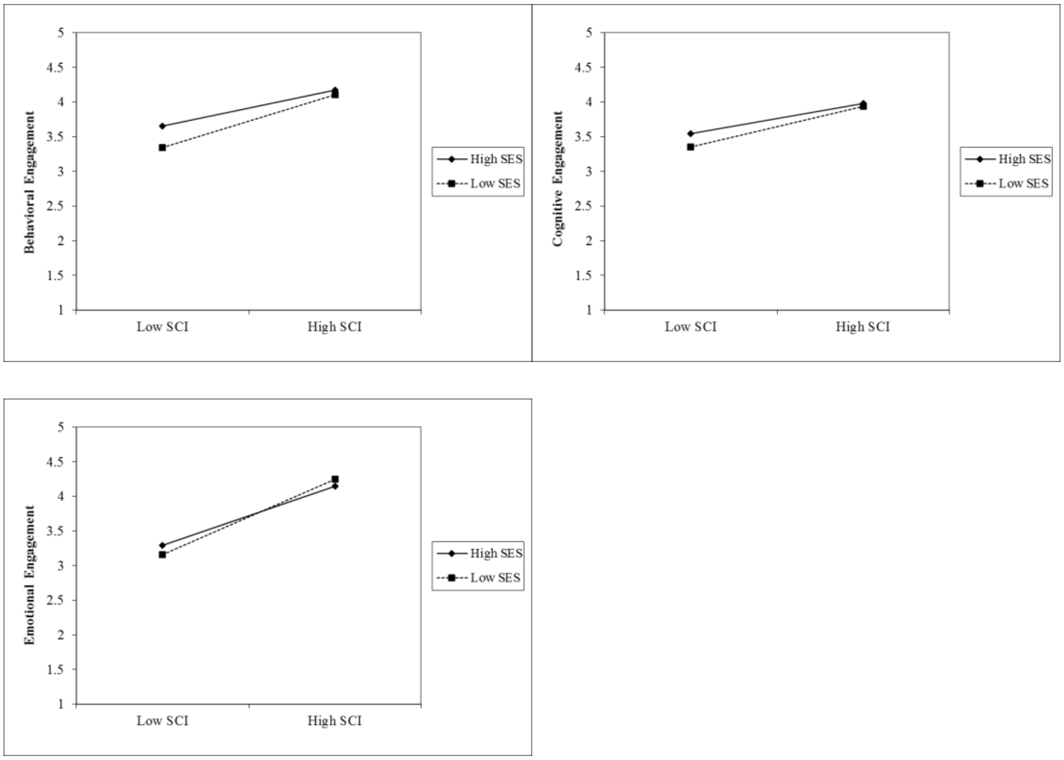

Figure 3: SES interaction effects on the types of engagement with low and high one standard deviation from the mean.

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