Threatened by Stereotype: An investigation of the effect of stereotype threat on female and minority student's STEM learning in the context of a computing intervention

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Abstract
To contribute to the growing field of STEM education, we examined the presence of stereotype threat for female and African American students during a large-scale computing intervention. Namely, this paper examines whether gender and race have an effect on students' self-perceived technology efficacy, technology anxiety, STEM attitude, and college expectations. In total, 1,085 student survey responses were analyzed in order to better understand the effects of stereotype threat on females' and minorities' STEM learning. The results suggest that gender was a consistent determinant of STEM attitude and technology efficacy. Furthermore, race was found to be a predictor of technology anxiety. In regards to college expectations, gender and race were not predictors. Instead, STEM attitude and self-efficacy were found to be positively associated with students' expectations to attend college.
Keywords: STEM; stereotype threat; minority; gender.
Citation: Huang, K-T., Cotten, S., Ball, C. (2015). Threaten by Stereotype: An investigation of the effect of stereotype threat on female and minority students' STEM learning in the context of a computer intervention. In *iConference 2015 Proceedings.*

Acknowledgements: This project was funded by a grant from the National Science Foundation (DRL-0918216; Shelia R. Cotten, PI). The views expressed in this manuscript reflect those of the authors and not the National Science Foundation.
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1 Introduction

Science, technology, engineering, and mathematics (STEM) education has been a focus of digital divide research since researchers and educators began examining the impacts of technology based disparities. The US educational system has been incorporating technology into schools in order to help prepare students for an information-based society in which digital skills will be increasingly important. However, despite the goal of disseminating computers among schools nationwide there still remain persistent gaps in computer access for some students. These gaps in computer access may have long-term effects on students' by not only limiting future career options but also influencing their career interests as a whole.

In particular, resent research has revealed that the underrepresentation of women and minorities in STEM related fields is actually getting worse. For example, the ratio of women in computer science has declined from 30 to 20 percent between the years 1984 and 1999 (Burke, 2007). These findings indicate that the barriers created by racial and gender based stereotypes may hinder entrance or interest in STEM related careers. Furthermore, these negative stereotypes could even have an impact on STEM related performance via the concept of stereotype threat. Briefly, stereotype threat is the theory that certain people may be at risk for internalizing the negative stereotypes that out-groups hold in regard to their particular in-group. People are susceptible to the negative effects of stereotype threat from early childhood through old age. Previous research has found that the negative expectations or beliefs regarding one's racial-ethnic group can have a negative influence on achievement (McKown, 2012). Therefore, it is imperative that we examine the impact of stereotype threat on STEM education as well as its effects on children's technology self-efficacy and attitude.

Furthermore, the research surrounding the possible effects of computing interventions on stereotype threat is still limited. The purpose of this study is to examine if the effects of stereotype threat on females and minorities exist in the context of a computing intervention. Therefore, this paper investigates the following questions: Does gender and race have an impact on STEM attitude, perceived self-efficacy, and anxiety toward using technology in early childhood? Did the computing intervention have an impact on the STEM-related outcome variables for women and minorities? Also, will the results of this study be consistent with the concept stereotype threat? In order to answer these research questions we must first begin by examining the theoretical background for this study.

2 Literature review

2.1 Stereotype threat

What is stereotype threat? A frequently cited definition of stereotype threat is “being at risk of confirming, a self-characteristic, a negative stereotype about one’s group” (Steele & Aronson, 1995, p.797). To be more specific, it is a “situation-induced threat” that applies other’s stereotypes to oneself, which will later have a negative impact on one’s performance related to the aforementioned stereotype (e. g. Lee & Nass, 2012). Some research also applies social identity theory to help explain stereotype threat by stating that individuals will conform to negative stereotypes associated with their groups (e. g. Walton & Cohen, 2007). For example, African American students might be affected by academic related stereotypes which could have an impact on their ability to perform on standardized tests. Conforming to other’s negative stereotypes can affect how people evaluate themselves and perform tasks related to the said stereotype. In other words, stereotype threat may unconsciously influence people to change or redefine their self-concept by adopting negative stereotypes regarding their social group. The negative self-evaluations that stem from stereotype threat may further prevent people from having the motivation to achieve in certain domains, such as STEM related disciplines.

Unfortunately, the research regarding the mechanisms that operate behind stereotype threat is still inconclusive. However, several negative effects have been linked to stereotype threat, including higher anxiety (e.g. Spencer, Steele, & Quinn, 1999), lower performance expectations (e.g. Oswald & Harvey, 2000/2001) and lower self-efficacy (e.g. Inzlicht & Kang, 2010). The literature reviewed for this study mainly focuses on the factors that are highly associated with stereotype threat: anxiety, domain specific attitude, self-efficacy and, self-expectation.

2.2 Anxiety, self-efficacy, self-expectation, and stereotype threat

Anxiety has been found as a result of stereotype threat when individuals conform to negative stereotypes about their group (Steele, 1997). However, the role of anxiety in the relationship between stereotype threat and performance is inconsistent. Some studies have found that anxiety has a mediating effect on the relationship between stereotype threat and performance (e.g. Osborne, 2001), while others have not (e.g. Spencer, Steele, & Quinn, 1999). Some researchers argue that the anxiety produced via stereotype threat actually occurs before individuals perform the relevant task (e.g. Schimel, Arndt, Banko, & Cook, 2004). Overall, despite some inconsistencies regarding the role of anxiety, it can still be said that anxiety accompanies stereotype threat while performing certain relevant tasks. In other words, stereotype threat is positively associated with increased anxiety.

Stereotype threat not only enlarges individual’s anxiety, it may also influences an individual’s self-efficacy and attitude associated to specific domains while performing a certain task (Inzlicht & Kang, 2010; Lee & Nass, 2011). By activating people’s self-doubts, stereotype threat undermines individual’s performance (Steele & Aronson, 1995). In other words, the negative stereotypes applied to a group can cause individuals to have doubts regarding their own ability, which can then have a subsequent negative impact on their self-efficacy.

Furthermore, the self-doubts caused by stereotype threat may influence individual’s expectations about their ability to perform a task in the long run. People who face stereotype threat have to deal with increased anxiety and lowered self-efficacy, which may also result in the negative expectancies (Stangor, Carr, & Kiang, 1998) or the loss of motivation to pursue certain fields (Keller & Dauenheimer, 2003). For example, people that experience STEM related self-doubts caused by internalized negative stereotypes may be less motivated to learn about STEM subjects or choose STEM careers. In other words, stereotype threat can activate people’s self-doubts which can then negatively affect their motivation to pursue certain domains/fields.

In sum, it is reasonable to hypothesize that people confirming negative STEM related stereotypes will have higher anxiety toward using technology, lower technology self-efficacy, and a less positive attitude toward STEM fields. Furthermore, STEM interest is usually linked to a higher motivation for future education. Therefore, it is also hypothesized that people who face STEM related stereotype threat will have less motivation to pursue future education.

2.3 Gender, race, and stereotype threat

Stereotype threat is usually a danger to groups that that have some sort of negative stereotype imposed upon them (Steele, 1997; Steele & Aronson, 1995; Oswald & Harvey, 2000/2001). Previous research on stereotype threat primarily focuses on, but is not limited to, race and gender (Lee & Nass, 2012). For example, research has found that stereotype threat has a negative impact on African American students' academic performance (Steele & Aronson, 1995). Further still, research has found that women's math performance can suffer when faced with the threat of negative stereotypes (Spencer, Steele, and Quinn, 1999). In other words, the hidden barriers erected by negative stereotypes, can influence females' and minorities' self-concepts, which might undermine their expectation of entering certain career fields.

The fact that women and minorities remain underrepresented in STEM fields may be an indicator that these groups are wrestling with negative stereotypes related to STEM subjects and careers. Previous research has found that stereotype threat affects women's mathematics performance (Inzlicht & Ben-Zeev, 2000, 2003; Spencer, Steele, & Quinn, 1999) as well as African Americans' standardized test performance (Steele & Aronson, 1995; Davis, Aronson, & Salinas, 2006). By increasing anxiety and decreasing self-efficacy, this situational-induced threat can influence individuals to perform poorly, which is consistent with the stereotype imposed on their social groups. This study hypothesizes that women/minorities may experience stereotype threat that decreases their attitude toward STEM subjects/careers, self-perceived technology efficacy, anxiety toward using technology, and motivation for future education. Therefore, this study proposes four sets of hypotheses:

- Male students will have higher scores on (a) self-perceived technology efficacy, (b) STEM attitude, and lower scores on (c) Anxiety toward using computers when compared to female students (hypothesis 1).
- Non African-American students will have higher scores on (a) self-perceived technology efficacy, (b) STEM attitude, and lower scores on (c) Anxiety toward using computers when compared to African American students (hypothesis 2).
- Students that have higher scores on (a) self-perceived technology efficacy and (b) STEM attitude will also have higher scores on their expectation to attend college (hypothesis 3).
- Expectations to attend college for minorities and women will be mediated by self-perceived technology efficacy (hypothesis 4).

3 Method

3.1 Data collection and sample

The ICAC program was a multiyear and multi-school technology focused intervention, which was implemented in a primarily urban area of the southern United States. The demographic composition of the school district, 95% African American and 89% of students receiving free or reduced price lunches (Alabama Department of Education, 2015), made it an ideal setting for an intervention focused on increasing the number of minority students interested in STEM related careers. Fourth and fifth grade teachers and students participated in various activities over the course of the program. Teachers participated in computer-based trainings during the summers and the school year where they learned to integrate computing across their curriculum. Trainings focused on blogging, computer programming, creating tables and graphs using spreadsheets, and various other activities to promote student interest in STEM. Teachers were expected to integrate what they learned using technology in the classroom. They received support from ICAC team members during classroom integration. Students were expected to benefit from the program primarily through teacher implementation. Thus, the trainings employed self-directed learning experiences with computers to increase students' self-efficacy and expectancies for success. Furthermore, the students' subjective task value for academics reinforced the value of higher education through the benefits of STEM careers.

Data for this manuscript was drawn from the pre and posttest surveys of 1,666 students. Data collection occurred at the beginning and end of the 2012 school year (Fall 2012 and Spring 2013 respectively). Student participation in the surveys was voluntary and all students were provided with incentives whether they completed the survey or not. Over 95% of the students chose to participate in the survey. Of the 1,666 students who participated in either the pre or posttest survey, only 1,201 students completed both surveys. This reduced number of completed surveys was due in part to student absences as well as a high number of field trips and other activities that took place at the end of the spring semester when the posttest surveys were administered.

After trimming cases with missing values on key variables there were 1.085 students included in the regression analysis. Key variables included: gender, age, race, computer anxiety, STEM attitude, self-perceived technology efficacy, and college expectations. The results of the following analysis were not significantly different after removing the missing data. Thus, reducing the sample size was not considered to be an issue in this study.

3.2 Dependent variables

In order to measure the STEM-related variables, this study included a series of items derived from the Birmingham Youth and Technology Study (Cotten, 2010). The dependent variables in this paper include: self-perceived technology efficacy, STEM attitude, and students' college expectations in the future.

Self-perceived technology efficacy was measured using a five-item scale. This scale included questions asking students to rate how proficient they were at using a computer or laptop (not the XO), a tablet computer (iPad, Kindle, Fire, etc.), the Internet, a cell phone, and a game system (Xbox, PS3, PSP, Game Boy, Game Cube, Wii). The response categories ranged from 0 to 4 where 0 indicated "I do not use" and 4 indicated "very good". After summing the scores of the five items the scale ranged from 5 to 20. The scales had acceptable reliability during both the pretest (α=0.67) and the posttest (α=0.61).

STEM attitude was measured using a seven-item scale. The scale questions included: "I think science is cool", "I think math is cool", "I like technology", ""knowing math will be important for me to get a good job", "knowing how to use technology and computers will be important for me to get a good job", "I would like to get a job as a scientist when I am older", and "I would like to get a job working with computers and technology when I am older." The scores for each item ranged from 1 (disagree) to 3 (agree). After summing the seven items the scores ranged from 3 to 21. The scale had acceptable reliability during both the pretest (α=0.58) and the posttest (α=0.52).

Computer anxiety was originally measured using a 16-item scale which asked students' about their emotional anxiety toward using computers. After conducting a reliability analysis, six items were eliminated from the scale. The final scale included questions such as: "computers make me uncomfortable", "using computer does not scare me at all", and "I am not good with computers" (Selwyn, 1997). The scores were then averaged resulting in an overall computer anxiety score. This scale had an acceptable reliability (α =0.61). Lastly, students' expectations to attend college were measured by a single item: "Do you think you will go to college". The responses ranged from 0 to 2 (0=no, 1=maybe, 2=yes).

3.3 Independent variables

Ideally, when examining the concept of stereotype threat there would be a measure of student's social identity. However, asking students about their social identity directly might produce some disadvantages. For example, the pretest questions might trigger the participants to begin considering the stereotypes associated with their social group identity resulting in a testing threat to internal validity. Therefore, this study simply asked students for their gender and race. In this study, gender (male = 1, female = 0) and race (non-African American = 1, African American= 0) were recoded as dummy variables.

3.4 Control Variable

There was only one control variable used in the regression analyses – age. Age was a continuous variable that required students to answer how old they were in years.

3.5 Analysis

A series of Ordinary Least Squares (OLS) Regressions were used to predict the change in students' gender, race, technology self-efficacy, and STEM attitude. Multilevel analyses were considered, but none of the intraclass correlation coefficients for the relationship between the 12 schools and outcome variables were large enough to use multilevel analysis. The effects of gender and race on students' expectations to attend college were also examined. All analyses were conducted using SPSS 20.

4 Results

4.1 Descriptive and T-test

Preliminary analyses were conducted to ascertain the descriptive statistics of the sample set (N = 1085). Of the total sample set, 50.1% were males. Participant's age ranged from 9-13, with a mean of 9.72 years old.

Descriptive statistics for both of the outcome variables revealed a slight but statistically significant change between the pre and posttest (Table 1). Students' self-perceived technology efficacy and students' STEM attitude actually decreased over the course of the intervention by 1.33 points and 1.85 points respectively. The pre to posttest difference was significant ($p < 0.001$). Interestingly, the results show that the computing intervention was not associated with statistically significant improvements across the two STEM related outcome variables used in this study.

In addition to descriptive statistics, two sets of independent sample T-test were conducted to compare the difference between groups. For the race variable, it was found that African Americans did indeed have higher anxiety toward using technology when compared to Non-African American students (Table 2). For the gender variable, it was found that male students did indeed have higher STEM attitude scores when compared to female students. Additionally, male students also had higher technology self-efficacy and lower technology anxiety scores compared to female students; however, the difference was not significant (Table 3).

	Pretest		Posttest		Change	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
Technology Efficacy	17.30	3.25	15.97	4.22	1.33***	4.15
STEM Attitude	17.72	2.78	16.87	2.38	1.85***	2.94
College Expectation	1.72	0.44	1.80	0.45	0.02	0.54

Table 1: Change in self-perceived technology efficacy and STEM attitude before and after computer intervention. *Notes*: p-values: * p<0.05 **p<0.01 ***p<0.001

	Non-African American		African American		Difference	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
Computer Anxiety	11.28	2.61	11.81	2.77	-0.53*	0.22
Technology Efficacy (T1)	17.39	3.19	16.88	3.51	0.50	0.28
Technology Efficacy (T2)	16.08	4.19	15.45	4.33	0.63	0.34
STEM Attitude (T1)	16.87	2.33	16.89	2.64	-0.02	0.21
STEM Attitude (T2)	18.76	2.70	18.62	3.10	0.14	0.22

Table 2: Difference in computer anxiety, technology efficacy, and STEM attitude between races. *Notes*: p-values: * p<0.05 **p<0.01 ***p<0.001

	Male		Female		Difference	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
Computer Anxiety	11.71	2.70	11.73	2.81	-0.02	0.17
Technology Efficacy (T1)	17.42	3.15	17.18	3.34	0.24	0.20
Technology Efficacy (T2)	16.02	4.18	15.92	4.26	0.10	0.26
STEM Attitude (T1)	17.12	2.48	16.61	2.26	0.51**	0.14
STEM Attitude (T2)	18.96	2.96	18.51	2.54	0.44**	0.17

Table 3: Difference in computer anxiety, technology efficacy, and STEM attitude between genders. *Notes*: p-values: * p<0.05 **p<0.01 ***p<0.001

4.2 Regression analysis

Based on these descriptive statistics and T-test analyses, a series of regressions were conducted to explore the relationship between the independent and outcome variables. In this study gender and race were hypothesized to affect students' technology self-efficacy, STEM attitude, and college expectations. All the hypotheses were tested using linear regression analyses. First, we examined the relationship between gender and race on self-perceived technology efficacy and STEM attitude across both the pre and posttest surveys (Table 4). Next, we examined the effects of gender, race on students' college expectations (Table 5). Lastly, we added the students' technology efficacy and STEM attitude into a number of regression models to determine if the computer usage variables were weakened by these psychological factors (Table 5).

The first regression analysis tested the effect of the STEM-related variables on emotional costs while controlling for student's age (Table 5). Gender was found to be a predictor of STEM attitude in the pre ($b = 0.465$, $p < 0.01$) and posttest survey ($b = 0.517$, $p < 0.01$). Gender was also found to be a predictor of technology efficacy in the posttest survey (b = 0.356, $p < 0.01$). In other words, male students tend to have higher scores on STEM attitude and technology efficacy than female students. Race was also found to be a predictor of technology efficacy in the pretest, which means that non-African American students were associated with higher technology efficacy. Age was also a predictor of STEM attitude in both the pre (b = -0.304, $p < 0.01$) and posttest surveys (b = -0.305, $p < 0.01$). This means that older students were associated with lower STEM attitude scores.

Regression analysis also tested the effect of independent and STEM-related variables on student's expectation to attend college in the future (Table 5). The results reveal that gender (b = -0.102, $p < 0.05$), race (b = -0.092, $p < 0.01$), STEM attitude (b = 0.021, $p < 0.001$) and self-perceived technology efficacy (b = 0.019, $p < 0.001$) are all predictors of student's college expectations in the pretest survey. In other words, higher scores on STEM-related variables were associated with higher college expectations. Interestingly, when controlling for the STEM-related variables, African American (b = -0.092, $p < 0.001$) and female (b = -0.102, $p < 0.001$) students were associated with higher college expectations.

Similar results were found when examining the posttest results for student's college expectations. Self-perceived technology efficacy (b = 0.015, $p < 0.001$) and STEM attitude (b = 0.031, $p < 0.001$) were still positively associated with students' college expectations. In other words, students that had higher scores on STEM-related variables were more likely to have stronger college expectations. Regarding gender, male students were associated with reduced college expectations in the posttest (b = -0.062, $p < 0.05$).

Comparing the results between the pre and posttest surveys, it was found that the effects of gender and race on students' college expectations were weakened in the posttest survey. In fact, race ceased to be a predictor in the posttest. Meanwhile, the effect of students' STEM attitude on students' college expectations increased in the posttest. Therefore, it is reasonable to argue that students' STEM attitude became more important and gender became less important over the course of the intervention regarding students' expectations to attend college in the future.

	STEM Attitude		Technology Efficacy	
	Pretest	Posttest	Pretest	Posttest
Age	-0.304**	-0.305**	-0.525	-0.008
Gender	0.465**	0.517***	0.215	0.676*
Race	0.153	0.014	0.356**	0.080
F	5.110**	7.500***	4.420**	1.560***
R^2	0.014	0.020	0.012	0.050

Table 4: STEM attitude and technology efficacy regressed on age, gender, and race. *Notes*: p-values: * p<0.05 **p<0.01 ***p<0.001

	College Expectation (T1)		College Expectation (T2)	
	Model 1	Model 2	Model 1	Model 2
Age	0.013	0.000	-0.015	-0.008
Gender	-0.079**	-0.102**	-0.045	-0.062*
Race	-0.116**	-0.092***	-0.024	-0.014
Technology Efficacy		0.021***		0.015***
STEM attitude		0.019***		0.031***
F	4.07**	9.64***	1.192	12.210***
R^2	0.01	0.04	0.01	0.05

Table 5: College Expectations regressed on gender, race, technology efficacy, and STEM attitude. *Notes*: p-values: * p<0.05 **p<0.01 ***p<0.001

5 Discussion

T-test and regression analyses supported most of the first hypothesis. Male students had higher STEM attitude scores on both the pre and posttest surveys. Male students also had higher self-perceived technology efficacy on the posttest survey. However, gender was not found to be a predictor of students' anxiety toward using computers. Therefore, these findings indicate that males and females have different attitude towards STEM fields and different levels of technology self-efficacy which is consistent with previous STEM-related studies (Spencer, Steele, Quinn, 1999; Lee and Nass, 2011). If we view these findings through the lens of stereotype threat then we may be able to explain these gender differences via situational-induced threats that females may have experienced in the context of the computing intervention. Interestingly, the difference between females' self-perceived technology efficacy was found before the computing intervention but it disappeared after the computing intervention which indicates that the intervention may have boosted females' technology self-efficacy.

The second hypothesis was partially supported. African American students had higher anxiety towards using technology when compared to non-African American students. Also, African American students had lower self-perceived technology efficacy on the pretest, which was measured before the computer intervention. Similar to the findings from the first hypothesis, these results provide evidence that African American students have different levels of computer anxiety and technology efficacy. Once again, the concept of stereotype threat may be able to provide some explanation for these differences which may also help us to understand why minorities are underrepresented in STEM fields.

The third and fourth hypotheses examined the relationship between technology efficacy, STEM attitude, and students' expectations to attend college. STEM attitude and self-perceived technology efficacy were associated with higher college expectations. In other words, students' with a more positive STEM attitude and greater technology self-efficacy were more likely to have higher expectations to attend college. This finding is meaningful because it indicates that computing interventions that hope to enhance computer efficacy and STEM attitude may also be able to motivate students to pursue higher education.

The results of this study also revealed that gender and race were predictors of students' college expectation. However, the direction of that relationship is in a different direction than the hypothesis. Female and African American students were found to have higher college expectations before the intervention. One reasonable explanation may be the stereotype threat produced an increased effect of students because they tried to fight back with the anxiety and negative stereotype they experienced.

When comparing the predictors of students' college expectations across the pre and posttest surveys it was found that gender and race were no longer predictors of students' college expectation in the posttest survey. This could be evidence that the negative effects of race and gender on students' college expectations disappeared after the computing intervention. This result provides a potential solution for diminishing some of the negative effects associated with the stereotype threat experienced by females and minorities related to entry into STEM fields.

6 Limitations

This study provides informative results based on a large-scale computing intervention that focused on enhancing students' STEM education. However, there are still some limitations in this study. First, stereotype threat is a concept that entails complex cognitive processes and the included scales did not cover all of the dimensions related to stereotype threat. For example, the degree of identification with ones' gender or race may affect how one deals with the negative stereotypes associated with their particular group. Also, stereotype threat is a situational-induced threat; therefore, knowing more specifics about when these threats become activated could provide more informative results. Future studies should add appropriate measures to gauge students' group identification as well as situational measures to better determine when stereotype threat becomes activated.

Another limitation of this study is related to the socio-economic status (SES) of the sample. The computing intervention analyzed in this study was in a high poverty, urban school district. The predictors worked very well in this particular environment. However, this sample may limit the generalizability of the findings of this study. Future studies should investigate students from more varied socio-economic backgrounds.

7 Conclusion

Despite these limitations, this study still provides several important contributions and implications to this area of research. First, this research found that females did indeed have lower self-perceived technology efficacy and STEM attitude. Likewise, it was found that African Americans had higher computer anxiety. These results are consistent with the findings of previous studies on stereotype threat. However, the influence of gender and race on students' self-perceived technology efficacy and STEM attitude became less important after the computing intervention. Therefore, it is reasonable to suspect that the computing intervention may have weakened the racial and gender based stereotype threat regarding these STEM-related variables.

Second, this study found that gender and race were not predictors of students' expectations to attend college. Instead, technology efficacy and STEM attitude were found to be predictors of college expectations. In terms of STEM education, this study found that STEM attitude and self-perceived technology efficacy were positively associated with higher college expectations. This finding may indicate a potential avenue to solve the drop out problem in this school district. In other words, computing interventions for elementary school students may help them develop their technology self-efficacy and STEM attitude which may also have the added benefit of increasing their college motivation.

Lastly, this research provides preliminary results articulating the effects of stereotype threat over the course of a computing intervention. These findings shed some light on a number of STEM related variables during an early stage of students' technology acclimation. In other words, these findings indicate that the impact of stereotype threat, which may occur in early childhood, can be weakened by computing interventions. Further research should focus on when stereotype threat influences students' technology efficacy and anxiety. Future research should also continue to investigate how computing interventions may be able to help prevent the occurrence of stereotype threat.

8 References

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8.1 Table of Tables