Predicting Math Achievement and STEM Career Interest Among Black Students: Limitations of Expectancy-value Theory

Expectancy-value theory (EVT; Eccles et al., 1983) was developed in exploration of gender-based differences in academic and vocational choices, namely the underrepresentation of girls and women in STEM coursework and careers. Racial or ethnic differences were considered distant influences, part of the "cultural milieu." Thus, EVT did not consider how racial or ethnic differences may directly shape students' motivations, the link between motivation and achievement, or between motivation and STEM career interest. Indeed, the majority of work in the motivation literature (including EVT) has been conducted with White samples (Graham, 1992; Kumar et al., 2021). As such, recent work has called into question EVT's colorblind approach, and its application to students of color (e.g., Gottlieb, 2018; Riegle-Crumb et al., 2011). The current study tests these colorblind expectations, by exploring the relations between motivation, achievement, and STEM career interest in a longitudinal study with Black students

Literature and Theory

EVT posits that students are motivated to achieve in academic areas they value and in which they expect to succeed (Eccles et al., 1983; Eccles & Wigfield, 2020). Subjective task values are comprised of interest, utility, cost, and attainment value. EVT was adapted in the 1980s to explain gender differences in academic and career choices. For instance, there is a gender gap in STEM careers, with more men in these positions than women (Rivers, 2017). Achievement differences do not explain this gap (Hyde et al., 2008). Instead, lower levels of subjective task values and expectancies of success explain why women on average opt for different coursework and have less interest in STEM careers (Jiang et al., 2020; Lauermann et

al., 2017; Nagy et al., 2006; Wang, 2012).

Only recently has EVT been used to explore racial and ethnic differences. For example, Black Americans are also underrepresented in STEM careers. There are also significant differences (on average) in educational experiences of Black and White students. For instance, schools with mostly White students tend to have more qualified teachers, with more years of experience, than schools with mostly students of color, where teachers tend to have lower expectations for their students (Flores, 2007; Mickelson, 2015; Riegle-Crumb & Grodsky, 2010). These different school experiences may shape students' motivations, achievement, and STEM career interest, or act as a barrier in pursuit of their interests. There are also differences in the educational experiences of Black boys and girls, including in mathematics, that question assumptions for the gender gap in STEM careers. Compared to Black boys, Black girls have higher GPAs on average, are more likely to be placed in advanced courses, and have higher levels of future education orientation (Kerpelman et al., 2007; Mickelson & Greene, 2006).

There is a small but growing literature that questions the applicability of EVT for students of color. A widely seen gender difference in mathematics expectancies of success in White students (Eccles et al., 1989) was not found in a sample of Black or Asian students (Seo et al., 2018). While EVT proposes that higher expectancies of success is related to later higher achievement, Kotok (2017) found a negative relation between expectancies of success and math achievement in Black high school students. Other studies have found weak or non-significant relations between math expectancies of success and math achievement in Black students, counter to EVT (Cheema & Kitsantas, 2014; Seo et al., 2018; Strayhorn, 2010). Similarly, there may be variability in the relation between subject task values and STEM career interests for students from different racial groups. Three subjective task values - utility, interest, and attainment value - predicted the concurrent STEM career interests of White 9th grade students. However, the only

EVT construct that was predictive for Black students was the subjective task value for cost, and that was limited to Black boys (Gottlieb, 2018).

There is a clear need for evaluating the usefulness of EVT for understanding academic and vocational choices among students of color, especially using longitudinal data. The current study explored the relations between mathematics motivation in 6th grade and mathematics achievement and STEM career interest in 10th grade among Black students. We considered two classifications of STEM careers, one excluding careers in medicine (as done by NSF) and one including careers in medicine, referred to as STEM+M (as done by U.S. Department of Labor), because of evidence that gender differences in STEM career interest and attainment differ based on whether medical careers are included (Dicke et al., 2019; Wiebe et al., 2018). We also included students' rating of their interest in a STEM career, as used in some past research (Lauermann et al., 2017).

Method

The study relied on a longitudinal study exploring mathematics achievement and STEM career interests in students of color and/or from families from limited resources, living in a metropolitan area of Tennessee, USA. The current study included participants' mathematics motivational beliefs when a majority of participants were in 6th grade and their math achievement and career interests when the majority of participants were in 10th grade. About 17% of the sample had been retained a grade level since enrollment in the study in pre-kindergarten, so were a grade-level behind. This study only included the Black students (n = 410). Race and gender were collected from school records, with 226 female and 184 male students.

Mathematics motivation in 6th grade was measured using items from the 2011 TIMSS Math Attitudes Questionnaire (Mullis et al., 2011). It contained measures of expectancies of

success (“I learn quickly in math”), interest (“I enjoy learning math”), and utility value (“I would like a job that uses math.”) Students responded on likert scale from 1 (agree a lot) to 4 (disagree a lot), and items were recoded so that higher scores correspond to higher levels of motivation.

Mathematics achievement in 10th grade was measured individually using the Comprehensive Mathematical Abilities Test (CMAT; Hresko et al., 2003) and the Quantitative Concepts subtest of the Woodcock-Johnson III (Woodcock et al., 2001). Mathematics achievement had also been assessed in 5th grade, using three portions of the KeyMath 3 Assessment: Numeration, Algebra, and Geometry (Connolly, 2007) and Quantitative Concepts. A composite measure of math achievement for each year was created by transforming raw achievement scores into z-scores, and then taking the mean of the z-scores.

There were three measures of career interest in 10th grade. The first was the average of students’ responses to two likert-scale questions: “I would like a career in STEM” and “I would like to major in a STEM field” rated on a scale from 1 (very unlikely) to 5 (very likely). The other two measures were based on students’ responses to the open-ended question: “Long term, what job(s) do you plan to have?” We categorized responses based on the 2020 O*NET-SEC (see https://www.onetonline.org/find/stem) and coded two ways: one that included medical careers in STEM, and one that excluded them. Information on the highest level of parent education (4 categories, from less than a high school degree to at least a bachelor’s degree) and income (4 categories, from less than $20,000 to greater than $50,000) was included as control variables in all models. Multiple imputation under the normal model was used to handle missing predictor and outcome variables (Graham, 2009). For continuous outcome variables, multilevel linear regression analyses with nesting for school attended in 10th grade was used, controlling for 5th grade math achievement, parent income, parent education. Gender (0 = girl, 1 = boy) was included as a variable of interest. Parallel binomial logistic regression analyses were used for the

two categorical outcomes.

Results

See Table 1 for correlations between achievement and expectancies of success, interest, and utility; and Table 2 for average scores on key variables by gender. In 6th grade, Black boys had higher levels of math expectancies of success and interest in math, but similar utility value, compared to Black girls (see Table 1). Boys and girls had similar math achievement in 5th grade and 10th grade. There were no gender differences in their rating of STEM interest, but Black boys were more likely to name a STEM career if medical careers were excluded while Black girls were more likely to name a STEM+M career.

Next, consider predictors of outcomes. For 10th grade math achievement, the only significant predictor was 5th grade math achievement (see Table 3). For 10th grade STEM career interest, the predictors varied with how the outcome was measured. When measured via rating of interest in a STEM career, no variable was predictive (see Table 3). When measured via identification of a career interest classified as STEM or STEM+M, gender and 5th grade math achievement were predictive, but none of the EVT constructs were (see Table 4).

Discussion and significance

There were gender differences between Black boys and Black girls in motivation and STEM career interest, but EVT could not help explain these gender differences. No EVT constructs from 6th grade significantly predicted math achievement or STEM career interest in 10th grade among a large sample of Black students in a metropolitan district. Two constructs, though, were marginally, positively predictive.

The marginal, positive relation between expectancies of success and future achievement adds to a body of research reporting the full spectrum of results for the relation between these

two constructs, with negative, positive, weak positive or no relations for Black students (Cheema & Kitsantas, 2014; Seo et al., 2019). Further, the current study suggests that the subjective task values of interest and utility may not be predictive of future achievement in mathematics for Black students.

In addition, the EVT constructs were never predictive of future STEM career interest. This aligns with findings of Gottlieb (2018) that math expectancies of success, interest, and utility value were not predictive of concurrent STEM career interest in Black 9th grade students, with STEM career interest coded from students' stated career interest. Overall, these EVT constructs do not seem particularly useful for predicting Black students' STEM career interest. Future research should consider alternative predictors, such as student mindset (Degol et al., 2017) and student STEM career knowledge (Blotnicky et al., 2018). Moreover, more work is needed that contextualizes Black students' school experiences. Racism and racist stereotypes, for instance, may prevent or dissuade students from taking advanced courses required for STEM majors and careers. With that in mind, Self-Determination Theory (SDT; Deci & Ryan, 2012), with its emphasis on one's need for relatedness or belonging, is a candidate for predicting Black students' achievement and STEM career interests.

We did find gender differences in some EVT constructs, as well as in STEM career interest. Black boys had higher expectancies of success and interest for math in 6th grade compared to Black girls, as has been found with White students (Eccles et al., 1989). However, Seo et al. (2018) did not find gender differences in 12th grade expectancies of success in Black students, so it is important to investigate whether gender differences persist through the end of high school for Black students. Further, gender differences in STEM career interest in our study varied with how STEM career interest was defined and measured. Categorizing medical careers as STEM careers flipped the gender difference, with more Black girls than Black boys

interested in STEM careers when medical careers were included.

EVT was developed in part to help understand the underrepresentation of girls and women in STEM coursework and careers (Riegle-Crumb et al., 2011). The current study illustrates that how STEM careers are defined and measured can influence the nature of gender differences. It also adds to growing concerns over the applicability of EVT for students of color (e.g., Gottlieb, 2018; Kotok, 2017; Seo et al., 2018). The colorblind approach taken in much of the past research on EVT does not reflect the fact that schools are not race-neutral environments (DeCuir-Gunby & Schutz, 2014; Gutierrez, 2013). There is an urgent need to refine theories of how motivation influences students' academic and vocational choices to consider how race and racism impact these relations.

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Table 1

Math motivation, achievement, and STEM career interest by gender

	Mean (Girls)	Mean (Boys)	t or χ^2	df	p
5th grade math achievement	-.04	.04	-.797	406.7	.426
6th grade math confidence	3.02	3.23	-3.40	404.5	.001**
6th grade math liking	3.42	3.53	-2.05	405.2	.04*
6th grade math utility	3.52	3.58	-1.34	404.9	.181
10th grade math achievement	-.04	.05	-.81	278	.42
10th grade STEM interest rating	3.27	3.43	-1.39	212.3	.164
Pct interested in STEM career	8.8	20.7	11.63	1	<.001***
Pct interested in STEM+M career	53.5	30.4	21.68	1	<.001***

***p<.001, **p<.01, *p<.05

Table 2

Linear regression results

Outcome	Parameter	Estimate	Std. Error	*t*	Sig.
10th grade math achievement	Intercept	-.04	.05	-.681	.496
	5th grade math achievement	.72	.035	20.6	.000***
	6th grade math expectancies of success	.10	.05	1.9	.06
	6th grade math interest	-.04	.06	-.78	.43
	6th grade math utility	.06	.08	.75	.45
	Gender	.04	.05	.65	.52
	Parental income	.03	.03	.92	.36
	Parental education	.06	.04	1.7	.09
10th grade STEM career interest	Intercept	3.3	.08	40.5	.000***
	5th grade math achievement	.12	.07	1.6	.11
	6th grade math expectancies of success	-.05	.11	-.5	.62
	6th grade math interest	.22	.13	1.7	.09
	6th grade math utility	-.14	.17	-.82	.41
	Gender	.16	.12	1.4	.19
	Parental income	-.07	.06	-1.1	.27
	Parental education	.15	.08	2.0	.05

Note: For gender, female was coded as 0 and male was coded as 1. ***p<.001

Table 3

Logistic regression results

Outcome	Parameter	Coefficient	Odds Ratio	Std. Error (Coefficient)	Std. Error (Odds Ratio)	*t*	Sig.
10th grade STEM interest	5th grade math achievement	.57	1.8	.25	.44	2.3	.023*
	6th grade math expectancies of success	-.32	.73	.35	.25	-.91	.37
	6th grade math interest	.35	1.4	.42	.59	.85	.40
	6th grade math utility	-.11	.89	.48	.43	-.24	.81
	Gender	1.2	3.4	.35	1.2	3.5	.001**
	Parental income	-.31	.73	.21	.15	-1.5	.13
	Parental education	.43	1.5	.26	.39	1.7	.09
10th grade STEM+M career interest	5th grade math achievement	.42	1.5	.15	.23	2.8	.005**
	6th grade math expectancies of success	-.24	.78	.22	.17	-1.1	.27
	6th grade math interest	.03	1.0	.26	.27	.11	.91
	6th grade math utility	-.19	.83	.33	.28	-.56	.58
	Gender	-1.0	.35	.24	.09	-4.3	.000***
	Parental income	.09	1.1	.13	.14	.71	.50
	Parental education	.25	1.3	.17	.21	1.5	.14

Note: For gender, female was coded as 0 and male was coded as 1. ***p<.001, **p<.01, *p<.05