Making Mathematics Relevant: An Examination of Student Interest in Mathematics, Interest in STEM Careers, and Perceived Relevance

Elizabeth Leyva (Corresponding Author)
Texas A&M University San Antonio (Mathematical, Physical and Engineering Sciences)
San Antonio TX, USA
eleyva@tamusa.edu

Candace Walkington
Southern Methodist University (Teaching & Learning)
Dallas TX, USA

Harsha Perera
University of Nevada Las Vegas (Educational Psychology and Higher Education)
Las Vegas NV, USA

Matthew Bernacki
University of North Carolina at Chapel Hill (Learning Sciences and Psychological Studies)
Chapel Hill NC, USA

Abstract

Community college students face difficulties in mathematics courses and may not understand the relevance of the topics they are learning to their intended career. When such connections are not made, mathematics courses can become barriers to pursuit of careers in Science, Technology, Engineering, and Mathematics (STEM). In the present study, we assessed student interest in mathematics and various STEM career areas and students' perceptions of ways mathematics is involved in STEM careers in order to better understand how these variables are related. We discovered that interest in mathematics predicted interest in many, but not all, categories of STEM and STEM-related careers. We also assessed how deeply the student was engaged with their current career pathway, and how this related to other variables. We found that students' depth of interest in their chosen career path was only associated with mathematics interest for some STEM careers. Finally, students' perceptions of how mathematics was used in their chosen career area predicted their interest in mathematics, and their interest in some STEM career areas.

Keywords: Mathematics education, STEM careers, mathematics interest, algebra

Making Mathematics Relevant: An Examination of Student Interest in Mathematics, Interest in STEM Careers, and Perceived Relevance

Required mathematics courses can be barriers for undergraduate students, including those pursuing STEM-related majors (Harackiewicz et al., 2012; Olson & Riordan, 2012). Required mathematics courses challenge students who are underserved in mathematics. A report on STEM attrition confirms that "College-level skills in mathematics… are a gateway to other STEM fields" (p. vi) and that "low-performing students with a high interest and aptitude in STEM careers often have difficulty with the mathematics required in introductory STEM courses with little help provided by their universities" (p. i; Olson & Riordan, 2012). These difficulties could lead promising, interested students to move away from STEM career pathways.

One possible explanation for the difficulties that these students encounter in mathematics coursework is the lack of perceived relevance of mathematics to their aspirational careers. Students are known to wonder, "When am I ever going to use this?" (Chazan, 1999). Maltese and Tai (2011) examined school-based factors that influence a student's choice of STEM majors and discovered that *interest* in and perceptions of the *usefulness* of mathematics and science, rather than achievement or course enrollment, was most predictive of degree choice. Wang et al. (2015) considered the implications of such motivations for representation in STEM learning and workforce populations, and attributed gaps in male-female STEM attainment to differences in STEM task value (i.e., interest, utility value, attainment value, and cost). In the present study, we conducted a more extensive examination of students' interests and perceptions about mathematics and STEM careers to better understand how interest in mathematics and interest in STEM careers are related. Further, we also considered how a student's perception of the ways mathematics is used in their chosen career area related to both their interest in mathematics and their interest in their chosen major/career.

The challenges that students face in mathematics are visible across K-12 and post-secondary contexts, but perhaps nowhere more so than at community colleges across the U.S. In the U.S., community colleges (also known as junior colleges or two-year colleges) are postsecondary public educational institutions that provide academic preparation for baccalaureate degrees, vocational training through certificates and credentials for workforce and career training, and continuing education for adults in the community (Kasper, 2002). With their open-door mission (Roueche & Baker, 1987), community colleges provide post-secondary educational opportunities to students who aspire to them, but who may not meet college admission standards or be financially prepared for the costs of higher education. Because of their widespread accessibility and low tuition, community colleges play a vital role in providing educational access, along with critical workforce training and job skills development. However, an open-door policy that affords admission to community college soon poses challenges as admitted students face numerous obstacles such as rigorous classes that they may be academically unprepared for, or a maze of course options and unclear pathways to completion (Dougherty et al., 2017). At community colleges, students are increasingly mainstreamed into College Algebra courses (e.g., Cullinane, 2012; Rutschow & Schneider, 2011) with little existing research examining the supports that are necessary for STEM majors to pass through this required course (Howell & Walkington, 2020).

Community college students on an algebra pathway are likely to be pursuing STEM degrees but are also more likely to be both under-prepared in mathematics and under-resourced in a number of ways that diminish their ability to succeed in their course (Mesa et al., 2014). Mesa et al. (2014) describe a variety of issues such students face. Students may have delayed enrollment because they have not taken mathematics in a number of years, and they may have deep-rooted misconceptions about mathematics. These students are also more likely to have competing family and work obligations and may have different goals regarding degree completion. Community college students often bear the financial burden of tuition without parental or family support, and many enroll only part-time. Finally, due to their increased exposure to everyday practical uses of mathematics that do not explicitly involve mathematical abstractions, they might have difficulty reconciling these experiences with academic mathematics concepts. At the same time, these students are more likely to be at a point in their lives when they see mathematics class as something that may directly further career goals. Little research has been conducted on classroom innovations to support the success of these students (Mesa et al., 2014), but some evidence exists that efforts to help students see the relevance of mathematics have promise (Kosovich et al., 2019).

In the local community college system where we conducted the present study, we spent several years investigating historical data relating to student characteristics, course-taking patterns, support-seeking behaviors, and trajectories through College Algebra (Howell & Walkington, 2015, 2016, 2020) and identified resources for student support during coursework as a key leverage point. This motivated our present aim to further examine how a student's STEM career interests and general perceptions of mathematics may relate, and how their perceptions of ways mathematics is used in their chosen career may further contribute to these relationships.

Theoretical Framework

Social Cognitive Career Theory

Theories of motivation, rooted in the social cognitive tradition, are increasingly used to explain academic and career interests. A major framework in the social cognitive tradition is the Social Cognitive Career Theory (SCCT; Lent et al., 1994; Lent & Brown, 2019). The SCCT aims to explain the processes governing the development and strengthening of educational and career-related interests. The SCCT holds that the development of career interests involves, inter alia, the interplay among (a) person inputs, such as gender, (b) prior learning experiences, and (c) prior academic interests. In the current study, we focused on gender and underrepresented status (URS) as critical person inputs (i.e., characteristics of students and their cultural milieu), career-mathematics perception (CMP) as an aspect of an individual's occupational knowledge that is cultivated from their prior learning experiences (i.e., learning experiences are information experiences that enhance knowledge of a certain activity or occupation (Bocanegra et al., 2016; Lent et al., 1994), and academic interest in mathematics as an important motivational precursor to the development of career interests (Lent et al., 2002).

The SCCT advances several propositions about the interlinkages among person inputs, prior learning experiences, prior academic interest, and later career interests. The model posits that career interests develop, in part, from prior learning experiences, including informational experiences that cultivate occupational knowledge. Specifically, students who develop greater occupational knowledge through informational experiences are more likely to develop and strengthen domain-relevant career interests as they have more information about the content and skills involved in the career. Access to prior informational experiences, which cultivate occupational knowledge, is itself influenced by person inputs (Lent et al., 1994, 2002), such as gender and URS status. Indeed, from a SCCT perspective, socialization processes tied to an individual's characteristics are likely to influence their access to relevant learning experiences, which may have downstream effects on their development of certain career interests (Lent et al., 2002). Additionally, from this theoretical standpoint, early academic interest in a specific domain may serve as the motivational basis for the development of latent career interest in comparable domains. This is because the experience of interest during an academic task, characterized by feelings of enjoyment and increased attention during the activity (Hidi & Renninger, 2006), may guide the student's movement towards domain-relevant activities that have clear connections to comparable career domains (Grigg et al., 2018).

Mathematics Interest

One important variable for community college students' success in their mathematics courses is their level of interest in mathematics. Higher levels of interest in mathematics and in other academic areas are associated with improved performance and learning in those areas in K-12 and post-secondary settings (Ainley et al., 2002; Harackiewicz et al., 2008; Kim et al., 2015; Murayama et al., 2013; Potvin & Hasni, 2014). Higher interest also tends to predict higher levels of important learning processes like attention, engagement, persistence, perceived competence, and use of learning strategies (Ainley et al., 2002; Flowerday & Shell, 2015; Hidi, 1995, 2001; Kim et al., 2015; Linnenbrink-Garcia et al., 2013; McDaniel et al., 2000; Schiefele & Krapp, 1996), which can serve as mediators and predictors of academic achievement.

Interest in mathematics or in a career area can first be triggered by experiences in or outside of classrooms that are relevant, salient, personally meaningful, or novel (Schraw & Lehman, 2001). This can elicit affective changes like increased engagement associated with *triggered situational interest* (Hidi & Renninger, 2006). When something triggers or catches a student's interest, it has further been found to focus attention and contribute to persistence in a learning task (Ainley et al., 2002) and improved learning as a result (Harackiewicz et al., 2008). Continued triggering of situational interest promotes *maintained situational interest* characterized by continued attention and persistence and the development of positive affective, knowledge-, and value-related responses (Linnenbrink-Garcia et al., 2010; Renninger & Su, 2012). As situational interest is maintained and knowledge and value are built, students' attitudes may also change – students may develop *emerging individual interest* in a content domain (Hidi & Renninger, 2006) and seek out future learning.

Interest in STEM Careers

Community college students have developed interest in the career areas they pursue over time. These vocational interests guide and sustain people's movement towards (and away from) certain educational and career pathways (Larson et al., 2014; Perera & McIlveen, 2018) and have been rated by individuals as the most important factor in their educational and career decision-making (Webb et al., 2002; Tang, 2009). Thus, normative changes in academic interests and career interest maturity may have implications for educational and career choices. Interests involving scientific and mathematical problem solving and analytic thinking most commonly found in mathematics and science school activities (Larson et al., 2014) are most predictive of mathematics educational and career pathways (Perera & McIlveen, 2018; Lapan et al., 1996; Ralston et al., 2004). These interests have been shown to remain stable from middle school to high school, decrease marginally in early college, and plateau thereafter (Hoff et al., 2017). This trajectory has been attributed to several factors, including students' declining self-beliefs regarding competence in mathematics during middle school, a trend which persists into high school (Jacobs et al., 2002). The effect may also be attributed to the lack of perceived personal relevance and little awareness of connections between mathematics subject matter to the world of work. However, increasing knowledge of the world of work in college, reflected by enhanced career maturity and readiness (Patton & Creed, 2001), may buffer against further declines in mathematics-related interests in the later college years (Hoff et al., 2017) as students increasingly recognize the potential applicability of mathematics to career pathways.

Accordingly, we explore students' perceptions of the mathematics involved in the careers to which they aspire as a key factor that relates to mathematics interest and career interest. The design of learning interventions for STEM career interest development must accommodate students at different phases of interest development for their aspirational career. Some students may have relatively fleeting, situational interest in a career path, characterized by little actual knowledge of what that career entails, while others may have sustained and developed individual interest that is characterized by knowledge, affect, and value (Renninger & Su, 2012).

Connecting Mathematics to STEM Careers

Because mathematics is a key element of many STEM careers, interest in mathematics may be an important contributor to community college students' tendency to be interested in STEM careers. Oz and Kloser (2021) found that mathematics disposition was an important positive predictor of STEM career attitudes, including identity, enjoyment value, utility value of STEM careers, with utility value having the largest effect size. Mathematics dispositions were also a significant negative predictor of perceived cost of pursuing a STEM career. Interest in mathematics may feed into whether students choose a STEM career area, how interested they are in different STEM career areas, and how deeply interested they are in the STEM-related career area they are currently pursuing. In addition, for those community college students who may have relatively well-developed interest in their careers, one approach to heighten their interest in mathematics might be to connect mathematics to their career of interest. In this way, students can discover or reinforce how their career will utilize mathematics.

A promising body of research on utility value interventions has shown that allowing students to see the usefulness or "utility" of STEM content they are learning to their lives and goals can improve their interest and learning. Having learners generate how course content is related to their lives through writing assignments has been found to be beneficial, particularly for students with low expectations of success or low academic performance (Hulleman & Harackiewicz, 2009; Hulleman et al., 2010; Hulleman et al., 2017). These approaches have also achieved success with first-generation college students (Harackiewicz et al., 2014), a group who are well represented among community college students, as well as students enrolled in developmental mathematics courses focused on algebra (Kosovich et al., 2019). A typical way these studies have learners generate relevance is by having students write a series of essays about how the content they are learning in class relates to their lives and interests. Having students evaluate interview quotes where different people describe the usefulness of mathematics has also been found to be an effective approach for enhancing utility value (Gaspard et al., 2015). Self-generating the utility value of learning particular academic content tends to be more effective than interventions that simply explain utility value to learners (Canning & Harackiewicz, 2015), and the latter can actually be damaging to students with low expectancy for success (Durik et al., 2015).

When considering career connections specifically, Netcoh (2017) explored personalized learning programs at three high schools, all of which accentuated connecting learning to personal interests and potential career goals. He found that these environments enabled students to feel autonomous, competent, and related, which in turn fostered intrinsic motivation. He also found that the programs allowed students to develop a clearer understanding of their own interests and career pathways. Similar research within high school and college STEM courses demonstrates the effectiveness of this approach. College courses that connected introductory biology and chemistry concepts to particular STEM careers that individual students indicated interest in (like forensics or energy research) also found positive results (Denofrio et al., 2007). Another study that indirectly manipulated utility value by examining the teaching of high school chemistry in the context of the STEM career of pharmacology found positive effects for student learning (Schwartz-Bloom et al., 2011). Finally, a study where students were asked to connect statistics learning to their future careers (among other activities) found these students placed greater value on statistics than a control group, and in some cases had higher exam performance (Acee & Weinstein, 2010).

This research all has a similar message: when instruction in STEM subjects is made relevant to students' lives, experiences, interests, and career goals, their interest in learning and their achievement can be enhanced.

Career-Mathematics Perception

Having students generate connections that show how mathematics may be relevant to their careers can only be an effective approach if students have some pre-existing ideas about how their career areas involve mathematics. We refer to this construct as students' "career-mathematics perceptions." Little research has been conducted on how much students know about the ways that the mathematics they are learning in school might be utilized in their careers. Walkington and Bernacki (2019) conducted a study that examined how much students knew about how mathematics was used in personal interest areas – like sports, video games, and cooking – and how this was associated with their outcomes from an intervention that attempted to personalize learning to these interests. They found that students with superficial knowledge of how mathematics was used in interest areas benefitted more from problems that made only superficial connections to their interest, while students with deeper understandings of how mathematics was used in their interest area benefitted more from problems that deeply connected mathematics to their interest area. They also found that degree of perceived knowledge of how mathematics was used in their interest area positively predicted learning efficiency for students who received personalized problems. Career-mathematics perception thus may be an important link between interest in mathematics and interest in STEM careers.

When we consider students' perceptions of how mathematics is used in their career area, we do not classify these perceptions as "correct" or "incorrect" – indeed, modern careers are far too broad-ranging and complex for there to be strict guidelines as to what mathematics is actually used for what careers. We rather classify this perception according to the complexity of the *mathematics* the student chooses to discuss in relation to this career. In this way, perhaps career-mathematics perception may be a subset of some larger construct of career-mathematics knowledge, and this perception is only a portion of the knowledge that an individual may have about an anticipated career.

A related issue is also not clear from prior research whether academic mathematics courses cover topics that provide an opportunity to draw authentic connection to career-related activities. Istas et al. (2021) conducted a study where they explored how engineers and other STEM professionals used concepts from College Algebra to do their jobs. They found that the vast majority of concepts from College Algebra were not actually used in these STEM careers. STEM professionals across fields of engineering tended to rely heavily on linear functions in day-to-day work, but not the more complex functional forms covered in College Algebra, nor the symbolic representations that are focal during instruction. Instead, they utilized arithmetic, tables, and graphs during their engineering workdays. This finding corresponds to a broader literature suggesting a mismatch between how mathematics is presented in school, and how it is used out of school (e.g., Hoyles et al., 2001; Lave & Wenger, 1991; Martin et al., 2009; Masingila et al., 1996; Saxe, 1988).

In sum, career-mathematics perception is a potentially important construct in understanding how learners respond to mathematical content intended to be "relevant" to their experiences. For career pathways that involve authentic use of associated mathematical concepts, it may be an important link between mathematics interest and STEM career interest.

Research Questions

Students' interest in learning mathematics is known to have important effects on their learning processes and outcomes. However, prior research has yet to clarify how mathematics interest relates to interest in specific STEM career areas. For example, is mathematics interest as important a factor for a student intending to be a biologist as for a student intending to be a physicist? Most prior studies have collapsed STEM career interest into a single category, assuming that students' level of interest of STEM careers is uniform over many different STEM career areas (e.g., engineering, biology, finance). It is also not clear how students' interest in mathematics predicts their depth of interest in different STEM or non-STEM career pathways – for example, two students might both plan to become physicians, but one might be deeply interested in and committed to this path, while another might only have passing interest in it that will not be sustainable through the challenges they encounter in their academic journey.

We further introduce the new concept of "career-mathematics perception," which to our knowledge has not been investigated in any prior studies, with the hypothesis that understanding how one perceives mathematics is used in different careers might be an important piece of the puzzle in understanding the relationship between mathematics interest and STEM career interest. We pursue research questions relating to these topics in the present study. Such questions about how mathematics interest, STEM career interest, and career-mathematics perception are related have not been previously investigated. In particular, students' perceived knowledge of how mathematics may be used in their STEM careers might be important to both their interest in STEM careers and their interest in mathematics.

In the present study, we thus investigated the following research questions:

1. RQ1: (a) What is the association between students' interest in mathematics and their interest in pursuing 14 categories of STEM and STEM-related careers?
   (b) What is the association between students' interest in mathematics and the depth of their interest in the career they most strongly wish to pursue?
2. RQ2: How are students' career-mathematics perceptions related to their interest in 14 categories of STEM and STEM-related careers, and to their depth of interest in their chosen career?
3. RQ3: What is the association between students' interest in mathematics and their career-mathematics perceptions and their choice of (a) a STEM or STEM-related versus non-STEM career area to pursue, and (b) a STEM career (e.g., engineering) versus a STEM-related (e.g., nursing) or non-STEM career to pursue?
4. RQ4: How are students' career-mathematics perceptions related to their interest in mathematics?

Methods

Participants

College Algebra students (n = 475) at a mid-size suburban community college in the Southern United States were given a Qualtrics survey regarding their interest in STEM careers, as well as their general interest in mathematics. The surveyed students were predominantly 18-24 years of age (87.5%), and mostly enrolled in face-to-face courses (90.5%). A small percentage of respondents reported that English was not their first language (14.5%), and the majority (62.7%) indicated that they were planning to pursue a STEM or STEM-related career. In this community college, many students opt to enroll in College Algebra, even though it is only a required course for students on STEM pathways. In the sample, approximately 37% of the students taking the College Algebra course were in non-STEM degree plans and could have taken other mathematics courses instead of College Algebra for their degree. In the sample, 49.3% of students identified as male students and 46.9% as female; 3.8% of respondents either chose "other" or chose not to respond to the gender question. When asked about ethnicity, the sample had approximately 68.6% who identified as non-Hispanic, 27.0% who identified as Hispanic, and 4.4% who did not specify their ethnicity. When asked about race, 65.3% of students identified as White, 8.0% as African-American, 6.3% as Asian, 4.6% as Native American, 0.4% as Native Hawaiian/Pacific Islander, 17.3% identified as Other, and 2.1% did not specify a race. Students could choose multiple categories of race and ethnicity. A variable to capture whether or not students were from racial/ethnic backgrounds that are under-represented in STEM (URS) was created and was coded a "1" for students who identified as Hispanic, African-American, or Native American; these categories were collapsed together because an explicit purpose of the larger project this research was part of was to consider ways to attract under-represented students to STEM career pathways and support their success on these pathways. The sample had 43.4% of the student participants coded as URS.

Protocol

A Qualtrics survey was administered to College Algebra students during a face-to-face class meeting time, for 15 minutes. Students who did not have a device to take the survey on or who did not wish to take the survey on a device were given a paper version of the survey. The survey was distributed in most of the face-to-face College Algebra sections in a community college system that contained students who were over 18 and was also shared with online sections of the course. Due to the nature of this particular college's campuses and the geographical difficulties in travelling to all campuses, some face-to-face sections were not invited to participate. Additionally, online sections had very low participation because all online classes at the time of the study were asynchronous in format. As an incentive, students were told that four randomly selected participants who completed the survey would receive a $100 gift card, and that some students would be selected to participate in follow-up interviews for $25 gift cards. There were 506 students that completed the survey across all of the College Algebra sections that were recruited (out of a total of 591 invited students). However, 20 students who did not give consent for participation in the study were omitted, and an additional 11 students were under the age of 18 and were omitted for that reason, leaving a final sample size of 475. Of the 475, 433 were enrolled in face-to-face College Algebra classes, 29 were enrolled in online College Algebra classes, and 13 did not indicate the modality of their College Algebra class. Total enrollment in College Algebra for that semester in the community college system was 841 for face-to-face classes and 252 for online sections. The lack of representation of students taking the course online is a limitation of this study.

Measures

CABIN Scales – Interest in 14 STEM and STEM-related Career Areas. After collecting demographic information, the Qualtrics survey presented the Comprehensive Assessment of Basic Interests (CABIN) scales (Su et al., 2019) which assessed students' level of interest in 14 STEM and STEM-related career areas (Table 1). The CABIN scales are adapted from the Basic Interest Markers (BIM) scales (Liao et al., 2008), and describe four behaviors relating to a specific career area. For example, for physical science, respondents considered "Analyze a mineral sample found on Mars" and rated interest in this activity on a 1-5 scale. All behavior ratings for each of the 14 career areas were averaged to create a composite score. Non-responses were excluded, and the number of missing responses reported per survey item is reported in Table 1. Detailed structural validity evidence for the CABIN scales, including second-order confirmatory factor analysis and exploratory SEM can be found in Su et al. (2019). Cronbach's alphas for all career clusters in our sample were greater than 0.9 (see Table 1).

Table 1

Descriptive Statistics of Survey Items

Variables with responses on 1-5 scale	**# of Missing Cases**	**Mean (SD)**	**Cronbach's Alpha**
Interest in CABIN Career Clusters			
STEM Education	20	3.04 (1.19)	0.957
Social Science	22	3.57 (1.06)	0.945
Carpentry/Woodwork	23	2.96 (1.16)	0.956
Mechanics/Electronics	20	2.64 (1.20)	0.955
Physical Science	21	3.39 (1.05)	0.925
Nature/Outdoors	23	3.26 (1.10)	0.934
Agriculture	22	2.73 (1.10)	0.935
Engineering	25	3.11 (1.13)	0.950
Finance	27	3.14 (1.20)	0.963
Information Technology	25	2.77 (1.26)	0.970
Life Science	27	3.18 (1.13)	0.941
Medical Science	28	3.48 (1.16)	0.970
Health Care Service	26	3.29 (1.21)	0.962
Mathematics/Statistics	26	2.78 (1.17)	0.939
Depth of Career Interest (STEM only, n = 312)	1	3.81 (0.63)	0.899
Mathematics Interest	36	3.10 (1.10)	0.959
Variable with responses on 0-2 scale		**Number in Each Category**	
Career-Mathematics Perception	63	Level 0 146 Level 1 191 Level 2 75	
Variables with 0/1 responses		**Number in Each Category**	
STEM or STEM-related Career Indicator	35	0 - No 131 1 - Yes 309	
STEM Career Indicator	35	0 - No 332 1 - Yes 108	

Depth of Interest in Chosen Career Scale. Following the CABIN scales, students were presented with an open-ended question to name their career of choice. Students then were asked to assess their depth of interest in that career. The items were adapted from the 15-item STEM

Tipping Points survey (Renninger & Schofield, 2014); one question was omitted because it did not make sense when the items were revised to reference students' chosen careers rather than subject areas (mathematics, science, engineering) – this item discussed the hierarchical nature of STEM disciplines. The questions asked students to respond to statements such as "How much do you know about this career?", "How much fun is this career?", and "Do you read about this career in your free time?". These depth of interest responses were averaged to create a measure of depth of students' career interest. Validation information for this survey, including results of an Exploratory Factor Analysis and regression result suggesting survey items predict persistence in STEM fields, can be found in Renninger and Schofield (2014). Because the depth-of-career-interest items were tied to an open-ended response that students gave about which career they were most interested in, only students that specified STEM-related careers were included in the analyses that related to this measure. Cronbach's alpha for this measure in our sample was 0.899 (see Table 1).

STEM Career Indicator. When students named their career of choice in the open-ended item, their responses were also classified according to a 0/1 variable specifying whether it was a STEM career (here, defined as careers in engineering, life science, information technology, social science, medical science, physical science, or mathematics/statistics). Their open-ended career choice was also classified according to a 0/1 variable specifying whether it was a STEM or STEM-related career (i.e., any of the 14 CABIN career clusters listed in Table 1). This distinction was based on NSF's classification of different categories of the Science and Engineering Labor Force (National Science Board, 2014).

Mathematics Interest Scale. With regards to mathematics interest, students were asked to first rate their level of interest in mathematics in general using the Linnenbrink-Garcia et al. (2010) scale (containing 8 items), which focuses on affect and value components of interest (example item: "I enjoy doing mathematics."). Cronbach's alpha for this scale as reported in Linnenbrink-Garcia et al. (2010) is 0.90; in our sample it was 0.959 (see Table 1). Scores were averaged for each student to create a composite score.

Career-Mathematics Perception Scale. Finally, students were asked an open-ended question regarding how mathematics was used in their specific chosen career, and responses were coded on a 3-point scale (Level 0 if no connection was made, Level 1 if students connected their career area to mathematics in simple ways that involved measuring, counting, addition or subtraction, and Level 2 if students made more sophisticated connections including algebraic applications (e.g., ratios or proportions) or applications beyond algebra. Algebraic connections often involved relationships between quantities that can vary, as conceptualized by Chazan (1999). This construct was created to measure a student's perception of how mathematics may be used in a chosen career and was referred to as the ordered factor variable "CMP" in the analysis below. Examples of responses are shown in Table 2 below. This scale was used in Walkington and Bernacki (2019) to measure students' personal knowledge about how mathematics was used in their interest areas and was found to predict learning efficiency for personalized problems and to moderate the effects of different kinds of personalization.

As can be seen from the entries for Level 0 in Table 2, responses would be coded as a Level 0 connection if students said they didn't know how mathematics was used in their career, stated that mathematics was not used in their career (Example 1), or if they gave a broad non-specific statement about the importance of mathematics to their career (Example 2). Although such broad statements may sometimes imply more specific knowledge that is not stated, we could code based only on what was written by the student. Many students may perceive in broad terms that mathematics is important but struggle to give specific applications of mathematics to different areas. Responses were coded as a Level 1 connection if they involved measurement, counting, or addition and subtraction. Many students described a single quantity that was measured in their field as an application of mathematics (Example 1 for Level 1 in Table 2), while many others described how simple financial transactions might be relevant to practicing a career (Example 2 for Level 1 in Table 2). Another commonly mentioned application of mathematics, given the career interests of students in our sample, was calculating medication doses. Although medication doses can be calculated based on body weight, unless the students specifically mentioned a second quantity (e.g., weight) that the first quantity (e.g., dosage amount) had a relationship to, these responses were considered Level 1. Responses were coded as Level 2 when the student made explicit a *relationship* between multiple quantities.

In Example 1 for Level 2 in Table 2, the student identifies the relationship between time and weather cycles as well as player skills and damage dealt. Connections were also coded as Level 2 if they involved probabilities, percentages, or ratios/proportions, since these concepts involve a relationship between a part and a whole. In Example 1 for Level 2 in Table 2, we also see connections made to loot drop and attack probabilities. In Example 2 for Level 2 in Table 2, we see connections made to aerodynamic percentages.

Note that in order to reach Level 2 on the scale, students would need to be pursuing a profession where there were quantities that were measured that may have part/whole, multiplicative or other relations between them. While this is likely universally characteristic of STEM careers, there were a few students pursuing non-STEM careers that it could be argued may not use any multiplication or numerical relationships. These included college students pursuing careers in history (6 students), theater or music (5 students), writing or English (8 students), or art (3 students). However, this was a very small proportion of the sample – for most careers students were pursuing, there were relatively clear ways in which concepts like proportion, ratio, percent, and multiplication could be used.

Table 2

Examples of responses that were coded as Level 0, 1, and 2 for career-mathematics perception

	Example 1	**Example 2**
Level 0	Well Math isn’t used any more, the x-ray machine does all the calculations for how much kvp and mas is needed to take the image of the desired area. Before more sophisticated machines were made, the x ray tech would have to input all the variables him/herself. (Career area: X-ray technician)	It's the foundation of all of engineering. (Career area: Aerospace engineering)
Level 1	Measuring body parts and looking for size of tumors. (Career area: Sonography)	Calculate expenses for business and products. (Career area: Veterinarian)
Level 2	Well developing any game system would require math. What's the formula for the loot this enemy will drop, or what's the chance if I attack this person will his friend intervene. Things like dynamic weather cycles in games would have variations depending on time of day. And damage dealt by and to the player for example, and what amounts it can be amplified by skills. Probability would factor in huge. (Career area: Video game development)	Math is used to find material failure points, aerodynamic percentages, and structural stability. (Career area: Mechanical engineering)

Analysis

Survey results were analyzed using linear and logistic regression models, controlling for both gender and URS (race/ethnicity that is under-represented in STEM) status. Gender was reported in all of our analysis tables as a factor variable with three possible values.

For the model that looked at depth of interest in a chosen STEM career as the outcome, an additional random effect (Snijders & Bosker, 1999) was added to the models for which STEM career the student was expressing interest in. For the first research question, a student's career interest (CABIN scale career area interest for RQ1a) or STEM Tipping Points depth-of-career-interest items (for RQ1b) served as the dependent variable in a linear regression model, with the students' mathematics interest and career-mathematics perception as predictors, controlling for demographic variables known to predict interest in specific careers (Grigg et al., 2018).

The second linear regression model (for RQ2) controlled for mathematics interest and utilized STEM career interest (CABIN scale career area interest or STEM Tipping Points depth-of-career-interest items) as the dependent variable with career-mathematics perception as the predictor variable. The regression analysis for RQ3 examined a student's chosen career area as the dependent variable, coded as a 0/1 depending on whether it was STEM-related or non-STEM-related (RQ3a), or on whether it was STEM or non-STEM (RQ3b). These dependent measures were related to the same predictors (student mathematics interest and career-mathematics perception) using logistic regression models. Finally, with regard to RQ4, linear regression models considered interest in mathematics as the dependent variable with career-mathematics perception as the predictor. In the regression tables, we report the unstandardized regression coefficients and their associated standard errors (B), as well as the standardized regression coefficients (β).

Results

Descriptive statistics are included in Table 1, and correlations are shown in Table 3. Regression analysis examined the relationships between a student's interest in mathematics, how mathematics was used in a specified career, and a student's interest in STEM fields. Results are described below, presented in response to the four research questions of this study.

Table 3

Matrix showing correlations among 15 measures

	Math Interest	*STEM Education*	*Social Science*	*Carpentry/ Woodwork*	*Mechanics/ Electronics*	*Physical Science*	*Nature/ Outdoors*	*Agriculture*	*Engineering*	*Finance*	*IT*	*Life Science*	*Medical Science*	*Health Care Service*	*Math/ Statistics*
Mathematics Interest	1														
STEM Education	0.34	1													
Social Science	0.10	0.27	1												
Carpentry/ Woodwork	0.09	0.27	0.20	1											
Mechanics/ Electronics	0.24	0.31	0.06	0.59	1										
Physical Science	0.14	0.27	0.33	0.32	0.38	1									
Nature/ Outdoors	-0.01	0.26	0.35	0.45	0.26	0.43	1								
Agriculture	0.07	0.29	0.34	0.52	0.39	0.41	0.71	1							
Engineering	0.28	0.35	0.25	0.53	0.64	0.45	0.35	0.44	1						
Finance	0.26	0.26	0.30	0.28	0.34	0.23	0.12	0.27	0.51	1					
Information Technology	0.35	0.34	0.10	0.33	0.51	0.34	0.11	0.21	0.63	0.49	1				
Life Science	0.13	0.26	0.30	0.24	0.21	0.49	0.39	0.44	0.39	0.20	0.27	1			
Medical Science	0.10	0.25	0.35	0.19	0.13	0.38	0.32	0.32	0.28	0.23	0.17	0.70	1		
Health Care Service	0.03	0.28	0.31	0.22	0.14	0.21	0.30	0.27	0.24	0.18	0.10	0.56	0.72	1	
Mathematics/ Statistics	0.78	0.43	0.15	0.23	0.36	0.25	0.13	0.20	0.49	0.37	0.49	0.29	0.23	0.15	1

RQ1: Relationship Between Mathematics Interest and STEM Career Interest

As shown in Table 4, a student's interest in mathematics was a predictor of a student's level of interest in many STEM careers from the CABIN scales (RQ1a). Specifically, mathematics interest predicted career interest in engineering ($\beta = 0.20$, $p < 0.001$), finance ($\beta = 0.20$, $p < 0.001$), information technology ($\beta = 0.27$, $p < 0.001$), mathematics/statistics ($\beta = 0.75$, $p < 0.001$), mechanics/electronics ($\beta = 0.11$, $p = 0.033$), STEM education ($\beta = 0.33$, $p < 0.001$), life sciences ($\beta = 0.13$, $p = 0.014$), physical sciences ($\beta = 0.11$, $p = 0.034$), and social sciences ($\beta= 0.10$, $p = 0.046$). A student's mathematics interest was not statistically significantly related to careers in carpentry, nature, healthcare, medical science, or agriculture. Career areas that did not have a statistically significant relationship to mathematics interest in any of the analyses were not included in the table. When examining how students' depth of interest in their chosen STEM career (stated in an open-ended item) was predicted by mathematics interest (RQ1b), we again see that a student's mathematics interest predicts depth of interest in a chosen STEM career area ($\beta= 0.20$, $p < 0.001$) for the subset of students interested in STEM careers. These results suggest that mathematics interest is an important predictor both of interest in pursuing STEM careers in general, and interest in pursuing the students' currently chosen STEM career.

Table 4

Part 1

Summary of Multiple Regression Models for Mathematics Interest, Perception of Mathematics Utility in Chosen Career, and STEM Career Interest by area

	CABIN-Engineering		CABIN-Finance		CABIN-Information Technology		CABIN-Mathematics/ Statistic		CABIN-Mechanics/ Electronics		CABIN-STEM Education	
	β	B(SE)^{SIG}	β	B(SE)^{SIG}	β	B(SE)^{SIG}	β	B(SE)^{SIG}	β	B(SE)^{SIG}	β	B(SE)^{SIG}
(Intercept)	0.00	2.07 (0.17)***	0.00	2.01 (0.18)***	0.00	1.24 (0.18)***	0.00	0.17 (0.12)	0.00	1.75 (0.20)***	0.00	1.84 (0.19)***
Gender												
Female		(ref)								(ref)		
Male	0.33	0.74 (0.10)***	0.29	0.69 (0.11)***	0.39	0.99 (0.11)***	0.07	0.16 (0.08)*	0.41	0.98 (0.11)***	-0.01	-0.01 (0.12)
Other	0.01	0.07 (0.51)	-0.06	-0.73 (0.56)	0.07	0.83 (0.55)	-0.01	-0.12 (0.37)	-0.03	-0.37 (0.53)	-0.07	-0.89 (0.57)
Under-Represented												
No		(ref)								(ref)		
Yes	0.11	0.25 (0.11)*	0.13	0.33 (0.12)**	0.06	0.16 (0.11)	0.05	0.13 (0.08)	0.08	0.19 (0.11)	0.12	0.29 (0.12)*
Mathematics Interest	0.20	0.20 (0.05)***	0.20	0.22 (0.05)***	0.27	0.31 (0.05)***	0.75	0.80 (0.03)***	0.11	0.12 (0.06)*	0.33	0.36 (0.05)***
CMP (Linear)	0.07	0.16 (0.11)	0.04	0.09 (0.12)	-0.03	-0.08 (0.11)	0.05	0.12 (0.08)	0.10	0.23 (0.38)	0.05	0.12 (0.12)
CMP (Quadratic)	0.06	0.10 (0.09)	-0.02	-0.04 (0.10)	0.08	0.17 (0.09)	0.05	0.10 (0.06)	0.43	0.84 (0.29)**	0.05	0.09 (0.10)
Mathematics Interest x CMP(L)									-0.02	-0.01 (0.11)		
Mathematics Interest x CMP (Q)									-0.33	-0.20 (0.09)*		

Table 4

Part 2

Summary of Multiple Regression Models for Mathematics Interest, Perception of Mathematics Utility in Chosen Career, and STEM Career Interest by area

	CABIN-Life Sciences	CABIN-Physical Sciences	CABIN-Social Sciences	CABIN- Agriculture	CABIN-Medical Sciences	Depth of Interest in Chosen STEM Career
Random Intercept – Career Area (SD)						0.14
	β B(SE)^{SIG}	β B(SE)^{SIG}	β B(SE)^{SIG}	β B(SE)^{SIG}	β B(SE)^{SIG}	β B(SE)^{SIG}
(Intercept)	0.00 2.84 (0.19)***	0.00 2.91 (0.17)***	0.00 3.37 (0.17)***	0.00 2.67 (0.18)***	0.00 3.36 (0.19)***	0.00 3.42 (0.14)***
Gender						
Female						
Male	-0.07 -0.15 (0.12)	0.15 0.31 (0.11)**	-0.17 -0.34 (0.11)**	0.01 0.02 (0.11)	-0.15 -0.34 (0.12)**	0.03 0.06 (0.08)
Other	0.04 0.43 (0.57)	0.01 0.15 (0.52)	0.04 0.47 (0.52)	-0.10 -1.06 (0.54).	-0.04 -0.41 (0.58)	-0.01 -0.25 (0.62)
Under-Represented						
No						
Yes	0.06 0.15 (0.12)	0.06 0.12 (0.11)	0.10 0.22 (0.11)*	0.07 0.17 (0.11)	0.03 0.08 (0.12)	-0.12 -0.09 (0.08)*
Mathematics Interest	0.13 0.13 (0.05)*	0.11 0.10 (0.05)*	0.10 0.10 (0.05)*	0.02 0.02 (0.05)	0.09 0.10 (0.05).	0.20 0.12 (0.04)***
CMP (Linear)	0.07 0.17 (0.12)	0.05 0.10 (0.11)	-0.05 -0.10 (0.11)	0.13 0.29 (0.11)*	0.08 0.17 (0.12)	0.05 0.06 (0.07)
CMP (Quadratic)	0.16 0.29 (0.10)**	0.17 0.30 (0.09)***	0.07 0.12 (0.09)	0.11 0.20 (0.09)*	0.11 0.22 (0.10)*	-0.12 -0.12 (0.06)
Mathematics Interest x CMP(L)						
Mathematics Interest x CMP (Q)						

RQ2: Relationship between Career-Mathematics Perception and STEM Career Interest

The results for RQ2 are also shown in the models in Table 4. Career-mathematics perception ("CMP") was a statistically significant, positive predictor of interest in multiple STEM careers including mechanics/electronics (β = 0.43, $p = 0.004$), life science (β = 0.16, $p = 0.003$), medical science (β = 0.11, $p = 0.029$), and physical science (β = 0.17, $p = 0.001$), after controlling for mathematics interest. Almost all statistically significant results occurred when considering the career-mathematics perception predictor as an ordered factor variable with a quadratic regressor term; only agriculture (β = 0.13, $p = 0.010$) showed a significant effect when considering career-mathematics perception as a linear term. This suggests that the relationship between CMP and outcome variables is not consistent for different levels of CMP. In particular, it means that the effect on the outcome variable of moving from CMP Level 1 to Level 2 is often greater than the effect on the outcome variable of moving from CMP Level 0 to Level 1.

Additionally, career-mathematics perception moderated the relationship between a student's interest in mathematics and interest in STEM careers for only one career area, mechanics/electronics ($p = 0.02$). In this case, the interaction term suggested that for students with low mathematics interest, career-mathematics perception was an important predictor of interest in mechanics/electronics. However, as mathematics interest increased, career-mathematics perception became less important.

RQ3: Relationship Between Mathematics Interest and Chosen Career Area Type

For the career area that students listed in the open-ended prompt, logistic regression models examined how the students' choice of STEM career area related to their interest in mathematics. Career choices related to any of the 14 career areas listed in Table 1 were considered "STEM-related careers," and career choices related to careers in engineering, life science, information technology, social science, medical science, physical science, or mathematics/statistics were considered "STEM" careers. Two 0/1 variables were created to use as outcome variables for whether or not the student had indicated interest in a STEM or STEM-Related career, and for whether or not they had indicated interest in a STEM career. As shown in Table 5, for all STEM/ STEM-related careers, as well as for STEM careers, there was a significant positive association between interest in the career area and a student's interest in mathematics ($d = 0.12$, $p = 0.041$; $d = 0.30$, $p < 0.001$, respectively).

While controlling for a student's interest in mathematics, a student's perception of how mathematics was used in their chosen career was also a significant predictor of whether a student expressed they were pursuing a STEM/STEM-related career ($d = 0.37$ for linear, $p = 0.017$; $d = 0.25$ for quadratic, $p = 0.034$) as well as whether they were interested in pursuing a STEM career ($d = 0.30$ quadratic, $p = 0.013$). Students' understanding of how mathematics was used in their specified career area did not moderate the relationship between whether a student chose a STEM career or a STEM/STEM-Related career, and their interest in mathematics ($p = 0.975$, $p = 0.113$, respectively).

These results suggest that both interest in mathematics and career-mathematics perception are important predictors of students' choice of STEM or STEM-related careers to pursue.

Table 5

Summary of Multiple Regression Model for Chosen Career Area and Mathematics Interest

	STEM/STEM-Related Career (0/1)			STEM Career (0/1)		
	B(SE)	*t*-value	*p*	B(SE)	*t*-value	*p*
(Intercept)	0.44 (0.37)	1.18	0.240	-3.61 (0.52)	-6.91	< 0.001***
Gender						
Female	(ref)					
Male	0.06 (0.24)	0.27	0.784	1.29 (0.28)	4.67	< 0.001***
Other	-2.19 (1.22)	-1.79	0.073.	0.91 (1.26)	0.72	0.471
Under-Represented						
No	(ref)					
Yes	-0.05 (0.24)	-0.22	0.824	0.10 (0.27)	0.38	0.702
Mathematics Interest	0.22 (0.11)	2.05	0.041*	0.55 (0.13)	4.07	< 0.001***
CMP (Linear)	0.67 (0.28)	2.38	0.017*	0.28 (0.24)	1.17	0.241
CMP (Quadratic)	0.45 (0.21)	2.12	0.034*	0.55 (0.22)	2.49	0.013*

RQ4: Relationship between Career-Mathematics perception and interest in mathematics

Results for RQ4 are shown in Table 6 below. A student's perception of how useful mathematics is for a given career area (Career-mathematics perception) was a strong positive predictor of a student's interest in mathematics ($\beta = 0.15$, $p = .010$).

Table 6

Summary of Regression Model Describing Career-Mathematics Perception and Interest in Mathematics

	β	B(SE)	*t*-value	*p*
(Intercept)	0.00	3.00 (0.11)	28.36	<0.001***
Gender				
Female		(ref)		
Male	0.13	0.29 (0.13)	2.23	0.026*
Other	0.05	0.96 (1.10)	0.87	0.385
Under-Represented				
No		(ref)		
Yes	0.06	0.14 (0.13)	1.09	0.275
CMP (Linear)	0.15	0.32 (0.13)	2.58	0.010*
CMP (Quadratic)	0.08	0.15 (0.11)	1.42	0.157

Reconsidering Career-Mathematics Perception as a Non-Ordered Factor Variable

As a final check to our analyses, we fit the career-mathematics perception variable as a regular factor variable, rather than an ordered factor variable, to see how results might change. This supplementary analysis was conducted based on the idea that it might not always make sense for Level 0 to be "below" Level 1, or Level 1 to be "below" Level 2. There was no change to the pattern of significant results in any of the models. In terms of the direction of the effects, we found Level 2 to be significantly greater than Level 1 in the life science, agriculture, physical science, STEM/STEM-related careers, and STEM careers models. In addition, we found Level 2 to be significantly greater than Level 0 in the Agriculture and STEM/STEM-Related Careers models. These results go in the sensible direction for the ordering as we had conceptualized it, but also suggest that the differences between Level 2 and the other two levels might be more important than the differences between Level 0 and Level 1. The only main effect result that did not fit with the ordering was for physical science interest – here Level 1 was significantly lower than Level 0. There were also some differences in how the interaction term for mechanics/electronics operated at Level 1 of CMP. However, overall, considering CMP as a non-ordered factor variable did not heavily impact our results or the associated conclusions.

Discussion and Significance

Social Cognitive Career Theory (SCCT; Lent et al., 1994; Lent & Brown, 2019) describes how the development of career interests involves factors including personal characteristics, prior learning experiences, and prior academic experiences. Here, we investigated the relationships between career interests and particular personal characteristics (gender, under-represented status), prior learning experiences (i.e., career-mathematics perception), and prior academic experiences (i.e., mathematics interest), and used SCCT to frame our investigation. Our study shed light on the relationship between these four categories of variables, making a novel contribution by considering career-mathematics perception as a potentially important factor, and by using a nuanced definition of interest in "STEM Careers" that involved 14 separate interest areas.

RQ1: Relationship Between Mathematics Interest and STEM Career Interest

The results indicate that a student's interest in mathematics is an important predictor of interest in multiple STEM and STEM-related careers and is also associated with students' depth of interest in a chosen STEM career. This is consistent with the findings of Oz and Kloser (2021), who measured STEM career interest in a way that was not specific to particular STEM sub-disciplines. However, it is interesting that in the present study, interest in mathematics was not related to interest in the STEM career areas of healthcare, medical science, and agriculture. All of these careers involve significant quantitative modelling of phenomena and/or applied quantitative reasoning, and mathematics could be seen as an integral part of the career practices. It is still telling that mathematics interest predicts interest in so many STEM career areas, and certainly this association makes sense given the importance of mathematics to all of these career areas. This echoes previous findings of Maltese and Tai (2011) that interest in mathematics is of critical importance when a student is choosing a STEM major (or not).

The finding that mathematics interest is a strong predictor of interest in STEM careers suggests it is not only important to encourage strong mathematics students to pursue STEM careers, but also potentially to find ways to enhance mathematics interest. It is important that students who are *not* interested in mathematics, who may not see themselves as a "math person," do not see STEM and STEM-related careers as closed off to them. Because mathematics courses are often gatekeepers to advanced STEM courses in areas such as chemistry and engineering, it is critical that interested students are not deterred from this pursuit by mathematics (Olson & Riordan, 2012). The results of this study require us to carefully consider how both parties (students that face fewer difficulties in mathematics and have a strong interest, as well as those that have less interest in mathematics and may face difficulties in mathematics courses) can be better engaged in the pursuit of STEM or STEM-related career pathways. Re-framing mathematics in post-secondary education as being tightly linked to career applications may allow students to gain the necessary mathematical skills they need to succeed in their careers, while at the same time not driving them away from STEM career pathways. Such an approach could enhance interest in mathematics, deepen knowledge of and interest in STEM careers, and better prepare students for the demands of using mathematics in the workplace (see Walkington et al., under review). However, such an approach would be difficult to implement – the way in which mathematics is used in STEM careers is very distant from the kinds of mathematics that are taught in College Algebra. Istas et al. (2021) found that STEM practitioners do not heavily use equations, instead focusing more on table, graphs, and informal calculations. They also do not often use functional relationships more complex than linear functions, and statistics is increasingly important rather than algebra.

RQ2: Relationship between Career-Mathematics Perception and STEM Career Interest

Students' perception of how mathematics is used in one's chosen career area is an important predictor of both interest in mathematics and one's interest in 5 of the 14 STEM career pathways. This builds on prior work that examined the role of students' personal perceived knowledge of how mathematics may be used in their personal interest areas, rather than career interest areas (Howell & Walkington, 2019; Howell et al., 2020). It is surprising that in the present study CMP did not have a larger role in predicting STEM career interest. It could be that perceiving how mathematics may be used in a STEM career might in some situations be negatively associated with interest in that career, due to mathematics anxiety or low mathematics interest causing the career to be less desirable as a result. In other cases, perceiving how mathematics may be used in a STEM career might signal that the student has had a lot of deep opportunities to engage with the authentic practices of the career that use mathematics, so we might expect a positive relationship. The relationship between these two variables may thus be very person- and context-specific.

CMP also did not significantly predict students' *depth* of interest in their chosen STEM career. In other words, students who reported being more interested in doing or doing more activities related their STEM career area did not tend to indicate significantly more or less career-mathematics perception. The literature on interest suggests that knowledge is an important component of students' interest in an area (Renninger & Su, 2012). Interest development theory details the complex innerworkings of component processes including independent and voluntary engagement of students in their interest areas, and the growing perception and competence that students gain through frequent engagement. Engaging with an interest area can improve both students' breadth and depth of perception of that interest area and can further influence their self-perceptions and motivations to pursue their interest in the future. Whereas we might expect that improving perceptions about the mathematics involved in a career might independently correlate to increased interest in that career, the additional relationship with motivational and affective processes could mediate or undermine this positive association.

We might have expected our results to show that having greater perceived perception of how mathematics may be used in your career would predict having greater interest in your career. The lack of a relationship could be caused by mathematics anxiety actually depressing interest in STEM careers that students realize will use a lot of mathematics. This may be specific to our population, community college students enrolled in College Algebra, given the experiences with mathematics they are likely to have had. As reported in previous research, community college students are more likely to be underserved in mathematics (Mesa et al., 2014) and thus may have increased negative feelings towards mathematics and mathematics-heavy careers. More research would be needed to further disentangle this relationship.

RQ3: Relationship Between Chosen Career Area Type and Mathematics Interest

In opposition to our mixed results for RQ2, we found that both interest in mathematics and CMP were significant, positive predictors of currently pursuing a STEM/STEM-related career (versus pursuing a non-STEM/STEM-related career), and of currently pursuing a STEM career. For the relationship between interest in mathematics and career choice, effect sizes suggest this relationship is stronger for what we called STEM careers (engineering, life science, information technology, social science, medical science, physical science, or mathematics/statistics) versus the full set of STEM and STEM-related careers. This is not surprising given that mathematics may be viewed as having a stronger relationship to careers in these fields and highlights the findings of previous researchers (Denofrio et al., 2007; Schwartz-Bloom et al., 2011; Acee & Weinstein, 2010) that mathematics instruction that is relevant to a student's interests or career choices can induce positive results. For the relationship between CMP and career choice, effect sizes were similar whether the student's interest was a STEM career or a STEM/STEM-related career.

The mixed results for CMP specifically might be explained by the following. In RQ2, we first asked for interest level in 14 career areas, whether or not the student planned to pursue them, and found only 5 career areas had positive relationships to CMP. We then examined whether students' depth of interest in a chosen STEM career related to CMP, for the subset of students pursuing a STEM career. In RQ3, however, we looked at all students, whether or not they were pursuing a STEM career, and conducted analyses on their chosen career and simply whether it was STEM or STEM-related or not – rather than how deeply interested in that career they were. So higher CMP might be associated with a greater chance of actually pursuing a STEM career versus a non-STEM career. But for those currently pursuing a STEM career, higher CMP might not be associated with depth of interest in or engagement with that career.

RQ4: Relationship between Career-Mathematics perception and interest in mathematics

For RQ4, we found that every increased level of CMP was associated with an increase in mathematics interest of 0.4 on a 5-point scale, which is a relatively large difference given prior research using this scale (Walkington et al., under review; Walkington, 2017). Given that knowledge and value are important components of interest, along with liking (Renninger & Su, 2012), it is not surprising that more perceived knowledge of how mathematics may be valuable to careers would be associated with more interest in mathematics. An important question is whether increasing CMP might increase mathematics interest, as mathematics interest is tied to a number of other important outcomes (e.g., Bernacki & Walkington, 2018; Kim et al., 2015). A study by Walkington et al. (under review) suggests that this could be the case – an intervention designed at building CMP did increase mathematics interest. The intervention involved students watching videos and solving problems about how mathematics was used in their chosen STEM career cluster. However, there were no direct assessments of whether or the degree to which CMP actually increased as a result of the intervention, making it unclear how exactly to attribute the results. This echoes other work on utility value interventions in mathematics (e.g., Gaspard et al., 2015) that have found positive effects.

Limitations

This study had several limitations. First, the study relied on self-report survey results at one time point, so all relationships are correlational in nature and cannot imply that one variable leads to or causes another. Second, the results may not generalize to populations other than the one described here – community college students enrolled in College Algebra in a particular community college system. Third, we did not get a strong survey response from students taking College Algebra in an online format (note that this study was conducted prior to the COVID-19 pandemic), so students who tend to enroll in online modality courses were likely systematically omitted from this study. Finally, our measure of CMP asked students how mathematics was used in their career area only, rather than how mathematics was used across each of our 14 STEM and STEM-related career areas of interest. Results may have been different had we given 14-15 different items; however, this would have also made the survey much more time-consuming. In addition, the construct of CMP might be more accurately assessed through interview methods where the interviewer can probe what perceptions the student does or does not have, rather than through the survey item.

Finally, there is the issue of the direction of the relationships between the different variables. Interest theorists propose dynamic relationships within the interest development process, and across multiple opportunities to engage with one's interest. One's interest is theorized to develop as a result of situational interest that is triggered and maintained by a stimulating task environment, and engagement in it affords exposure to the features of the task. Such exposure could enhance one's knowledge, competence, enjoyment, and valuing of the interest area, inducing a greater willingness to re-engage voluntarily and independently. Such maturation of interest is described as progression toward a "developing" then a "well-developed interest." Accordingly, we adopted a correlational approach and posit one direction that the relationship between features occurs. It is indeed the case that the relationships we model could occur in the opposite direction, and more likely, that these processes occur and reify each component of interest in a dynamic fashion. With that in mind, one key limitation of this study is that data were collected all at once and modeled using correlational analyses. Our assumptions about the directionality of effects observed are but one possible direction within what is a complex, dynamic, and iterative process best represented by (1) longitudinal data collection that could track growth in the components of interest, perhaps using cross-lagging of models to test directionality of effects , and (2) augmented with thicker descriptions of students' interest based on their prior knowledge of the interest area, mathematics, their intersection, and their tendencies as they engage with their interest pursuit.

Significance

By examining how student interest in mathematics relates to a student's interest in a specific STEM career, rather than looking at STEM career interest as a unidimensional construct, we gained insight into how a student's interest in mathematics is related (or not) to a STEM career interest. This association could have important implications for career counseling, academic advising, and pedagogical practices in STEM classrooms. We also examined the associations between a student's interest in mathematics and their *depth* of interest in various STEM pathways, again to augment the existing research on how mathematics interest can impact learning in mathematics courses. By examining the novel concept of "career-mathematics perception," we shed light on how CMP did seem to be related to interest in mathematics, but not necessarily to interest in all specific STEM career areas. As noted previously, further investigation into this construct will be needed to better understand the tangled relationship between career interest, interest in mathematics, and perception of how mathematics is used in a chosen career. But the introduction of CMP as a factor to consider could add to future research into how students can leverage mathematical interest, knowledge, and perception of careers in their pursuit of learning key mathematical concepts.

Our use of a community college sample was a contribution of the study, in that these findings contribute to a research area that is in need of further development. The results of this study shed light on how this under-studied group of students sees themselves as mathematics learners, how they conceptualize the mathematics found in various careers, and the ways in which they see themselves interacting (or not) with mathematics in a future career setting. Gaining a better understanding of these students and their ability to see themselves in various STEM and STEM-related career roles could contribute to workforce and technical training, to create authentic experiences that will help adult students to be better prepared for a future vocation. Additionally, knowing more about how this group of students perceives prospective careers and the role of mathematics in those careers can help to inform several critical processes outside of the classroom that nonetheless have a significant impact on credential completion and student success (e.g., curriculum development, academic and career advising, degree plan development, student engagement activities, tutor training). While community colleges are predominantly a U.S. construct, the need for postsecondary credentials and workforce training is a worldwide phenomenon. Increasing our knowledge of how adult students learn mathematics, and how to better relate a student's classroom experiences to their career interests, is a critical step in building technical or vocational training opportunities that can provide students with a gateway for further study, or a credential that allows for upward social mobility.

In the broader context of mathematics education, these findings add additional evidence to existing research studies that suggest that increasing relevance in mathematics instruction can motivate students to learn and achieve in mathematics. Interventions to increase mathematics interest and knowledge of how mathematics is used in various careers could contribute to increased interest in several STEM career areas, including Information Technology, Engineering, Finance, STEM Education, and Health Care Services careers. Mathematics is a critical component in the preparation for and subsequently the day-to-day practice within many STEM careers, and helping undergraduate students to make clear connections between the mathematics they are learning and the STEM careers they may pursue has the potential to improve students' outcomes in their mathematics courses by increasing students' interest in mathematics and in these career pathways.

This understanding has additional impacts on several crucial student success processes such as academic advising and degree plan development – knowing a student's interest in mathematics (or not) can assist advisors with conversations about degree choices, course selection, and the importance of persistence. In addition, understanding how students think about future uses of mathematics in their careers can inform textbook developers as they create the next generation of college mathematics textbooks to support under-served learners in community colleges. It is important to consider the career pathways of these students specifically, and the ways in which they will likely encounter and utilize mathematics in the modern workplace. STEM and STEM-related careers can be an important force of upward socioeconomic mobility for under-served students in community colleges and exploring ways to make mathematics relevant to these students' goals may allow for greater success in college courses. In addition, in cases where mathematical concepts are being taught in community colleges that do not have relevant CMP for most students' career pathways, higher education administrators involved in curriculum development and approvals should critically re-examine requirements and the justification for students learning this content.

Conflict of Interest Statement: On behalf of all authors, the corresponding author states that there is no conflict of interest.

Acknowledgements: This work was supported by the National Science Foundation under Grant #1759195. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation. The authors would also like to thank Brooke Istas, Min Wang, and the mathematics faculty and staff at our partner college for their efforts and support of this study.

References

Acee, T. W., & Weinstein, C. E. (2010). Effects of a value-reappraisal intervention on statistics students' motivation and performance. *The Journal of Experimental Education*, *78*(4), 487-512.

Ainley, M., Hillman, K., & Hidi, S. (2002). Gender and interest processes in response to literary texts: Situational and individual interest. *Learning & Instruction*, *12*, 411–428.

Bernacki, M., & Walkington, C. (2018). The Role of Situational Interest in Personalized Learning. *Journal of Educational Psychology, 110*(6), 864-881. https://doi.org/10.1037/edu0000250

Bocanegra, J. O., Gubi, A. A., & Cappaert, K. J. (2016). Investigation of social cognitive career theory for minority recruitment in school psychology. *School Psychology Quarterly, 31*(2), 241–255. https://doi.org/10.1037/spq0000142

Canning, E. A., & Harackiewicz, J. M. (2015). Teach it, don't preach it: The differential effects of directly-communicated and self-generated utility–value information. *Motivation Science*, *1*(1), 47-71.

Chazan, D. (1999). On teachers' mathematical knowledge and student exploration: A personal story about teaching a technologically supported approach to school algebra. *International Journal of Computers for Mathematical Learning*, *4*, 121-149.

Cullinane, J. (2012). Developmental education structures designed for the readiness continuum: Aligning the co-requisite model and student needs. Higher Ed Issue Brief No. 2. The Charles A. Dana Center, University of Texas at Austin.

Denofrio, L. A., Russell, B., Lopatto, D., & Lu, Y. (2007). Linking student interests to science curricula. *Science*, *318*, 1872-1873.

Dougherty, K., Lahr, H., & Morest, V. (2017). Reforming the American Community College: Promising Changes and Their Challenges. New York: Community College Research Center, Teachers College, Columbia University. Retrieved December 23, 2020 from https://ccrc.tc.columbia.edu/media/k2/attachments/reforming-americancommunity-college-promising-changes-challenges.pdf

Durik, A. M., Shechter, O. G., Noh, M., Rozek, C. S., & Harackiewicz, J. M. (2015). What if I can't? Success expectancies moderate the effects of utility value information on situational interest and performance. *Motivation and Emotion*, *39*(1), 104-118.

Flowerday, T., & Shell, D. F. (2015). Disentangling the effects of interest and choice on learning, engagement, and attitude. *Learning and Individual Differences, 40*, 134-140.

Gaspard, H., Dicke, A. L., Flunger, B., Brisson, B. M., Häfner, I., Nagengast, B., & Trautwein, U. (2015). Fostering adolescents' value beliefs for mathematics with a relevance intervention in the classroom. *Developmental Psychology*, *51*(9), 1226-1240.

Grigg, S., Perera, H. N., McIlveen, P., & Svetleff, Z. (2018). Relations among math self efficacy, interest, intentions, and achievement: A social cognitive perspective. *Contemporary Educational Psychology*, *53*, 73-86. https://doi.org/10.1016/j.cedpsych.2018.01.007

Harackiewicz, J., Durik, A., Barron, K., Linnenbrink, E., & Tauer, J. (2008). The role of achievement goals in the development of interest: Reciprocal relations between achievement goals, interest, and performance. *Journal of Educational Psychology*, *100*(1), 105-122.

Harackiewicz, J. M., Rozek, C. S., Hulleman, C. S., & Hyde, J. S. (2012). Helping parents to motivate adolescents in mathematics and science: An experimental test of a utility-value intervention. *Psychological Science*, *23*(8), 899-906. https://doi.org/10.1177/0956797611435530

Harackiewicz, J. M., Canning, E. A., Tibbetts, Y., Giffen, C. J., Blair, S. S., Rouse, D. I., & Hyde, J. S. (2014). Closing the social class achievement gap for first-generation students in undergraduate biology. *Journal of Educational Psychology*, *106*(2), 375-389.

Hidi, S. (1995). A reexamination of the role of attention in learning from text. *Educational Psychology Review*, *7*(4), 323-350.

Hidi, S. (2001). Interest, reading, and learning: Theoretical and practical considerations. *Educational Psychology Review*, *13*(3), 191-209.

Hidi, S., & Renninger, K. (2006). The four-phase model of interest development. *Educational Psychologist*, *41*(2), 111-127.

Hoff, K. A., Briley, D. A., Wee, C. J., & Rounds, J. (2017). Normative changes in interests from adolescence to adulthood: A meta-analysis of longitudinal studies. *Psychological Bulletin, 144*(4), 426. https://doi.org/10.1037/bul0000140

Howell, E., & Walkington, C. (2015). An examination of factors impacting college algebra readiness: Pathways through developmental mathematics. In Che, S. M. and Adolphson, K. A. (Eds.). *Proceedings of the 42nd Annual Meeting of the Research Council on Mathematics Learning.* Las Vegas, NV.

Howell, E., & Walkington, C. (2016). The role of support structures in the success of developmental mathematics programs. In Adolphson, K. and Olson, T. (Eds.). *Proceedings of the 43rd Annual Meeting of the Research Council on Mathematics Learning.* Orlando, FL.

Howell, E., & Walkington, C. (2019). An exploration of math attitudes and STEM career interests for community college students. In Weinberg, A., Moore-Russo, D., Soto, H., & Wawro, M. (Eds.), *Proceedings of the 22nd Annual Conference on Research in Undergraduate Mathematics Education* (pp. 1121-1122). Oklahoma City, Oklahoma.

Howell, E., & Walkington, C. (2020). Factors associated with completion: Pathways through developmental mathematics. *Journal of College Student Retention: Research, Theory & Practice*. https://doi.org/10.1177/1521025119900985

Howell, E., Walkington, C., Bernacki, M., & Istas, B. (2020). The connection between perception of utility in careers with math and STEM career interest. In Karunakaran, S.S., Reed, Z., & Higgins, A. (Eds.), *Proceedings of the 23rd Annual Conference on Research in Undergraduate Mathematics Education* (pp. 1168-1169). Boston, Massachusetts.

Hoyles, C., Noss, R., & Pozzi, S. (2001). Proportional reasoning in nursing practice. *Journal for Research in Mathematics Education*, *32*(1), 4-27.

Hulleman, C. S., Godes, O., Hendricks, B. L., & Harackiewicz, J. M. (2010). Enhancing interest and performance with a utility value intervention. J*ournal of Educational Psychology*, *102*, 880-895.

Hulleman, C. S., & Harackiewicz, J. M. (2009). Promoting interest and performance in high school science classes. *Science*, *326*(5958), 1410–1412.

Hulleman, C. S., Kosovich, J. J., Barron, K. E., & Daniel, D. B. (2017). Making connections: Replicating and extending the utility value intervention in the classroom. *Journal of Educational Psychology*, *109*(3), 387-404.

Istas, B**.,** Walkington, C., Bernacki, M., & Leyva, E. (2021). When am I (n)ever going to use this? How engineers use algebra (NSF DRL). Poster presentation at the 2021 American Society for Engineering Education Annual Conference, Long Beach, CA.

Jacobs, J. E., Lanza, S., Osgood, D. W., Eccles, J. S., & Wigfield, A. (2002). Changes in children's self-competence and values: Gender and domain differences across grades one through twelve. *Child Development*, *73*(2), 509-527. https://doi.org/10.1111/1467-8624.00421

Kasper, H.T. (2002). The changing role of community college. Occupational Outlook Quarterly, Winter, 14-21.

Kim, S., Jiang, Y., & Song, J. (2015). The effects of interest and utility value on mathematics engagement and achievement. In K. A. Renninger, M. Nieswandt, & S. Hidi (Eds.), Interest in mathematics and science learning (pp. 63-78). Washington, DC: American Educational Research Association.

Kosovich, J. J., Hulleman, C. S., Phelps, J., & Lee, M. (2019). Improving algebra success with a utility-value intervention. *Journal of Developmental Education*, *42*(2), 2-10.

Lapan, R. T., Shaughnessy, P., & Boggs, K. (1996). Efficacy expectations and vocational interests as mediators between sex and choice of math/science college majors: A longitudinal study. *Journal of Vocational Behavior*, *49*(3), 277-291. https://doi.org/10.1006/jvbe.1996.0044

Larson, L. M., Pesch, K. M., Bonitz, V. S., Wu, T. F., & Werbel, J. D. (2014). Graduating with a science major: The roles of first-year science interests and educational aspirations. *Journal of Career Assessment, 22*, 479. doi: 10.1177/1069072713498680

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge university press.

Lent, R. W., & Brown, S. D. (2019). Social cognitive career theory at 25: Empirical status of the interest, choice, and performance models. *Journal of Vocational Behavior* (Advance Online Publication). https://doi.org/10.1016/j.jvb.2019.06.004

Lent, R. W., Brown, S. D., & Hackett, G. (1994). Toward a unifying social cognitive theory of career and academic interest, choice, and performance. *Journal of Vocational Behavior*, *45*(1), 79-122. https://doi.org/10.1006/jvbe.1994.1027

Lent, R. W., Brown, S. D., & Hackett, G. (2002). Social cognitive career theory. In D. Brown (Ed.). *Career choice and development* (pp. 225–311). (4th ed.). San Francisco, CA: Jossey-Bass.

Liao, H.-Y., Armstrong, P. I., & Rounds, J. (2008). Development and initial validation of public domain Basic Interest Markers. *Journal of Vocational Behavior, 73*(1), 159–183. https://doi.org/10.1016/j.jvb.2007.12.002

Linnenbrink-Garcia, L., Durik, A., Conley, A., Barron, K., Tauer, J., Karabenick, S., & Harackiewicz, J. (2010). Measuring situational interest in academic domains. *Educational Psychological Measurement*, *70*, 647-671.

Linnenbrink-Garcia, L., Patall, E. A., & Messersmith, E. E. (2013). Antecedents and consequences of situational interest. *British Journal of Educational Psychology*, *83*(4), 591-614.

Maltese, A. V., & Tai, R. H. (2011). Pipeline persistence: Examining the association of educational experiences with earned degrees in STEM among US students. *Science Education*, *95*(5), 877-907.

Martin, L., Goldman, S., & Jiménez, O. (2009). The tanda: A practice at the intersection of mathematics, culture, and financial goals. *Mind, Culture, and Activity*, *16*(4), 338-352.

Masingila, J. O., Davidenko, S., & Prus-Wisniowska, E. (1996). Mathematics learning and practice in and out of school: A framework for connecting these experiences. *Educational*

studies in mathematics, *31*(1), 175-200.
McDaniel, M. A., Waddill, P. J., Finstad, K., & Bourg, T. (2000). The effects of text-based interest on attention and recall. *Journal of Educational Psychology*, *92*(3), 492-502.
Mesa, V., Wladis, C., & Watkins, L. (2014). Research problems in community college mathematics education: Testing the boundaries of K-12 research. *Journal for Research in Mathematics Education*, *45*(2), 173-192.
Murayama, K., Pekrun, R., Lichtenfeld, S., & Vom Hofe, R. (2013). Predicting long-term growth in students' mathematics achievement: The unique contributions of motivation and cognitive strategies. *Child development*, *84*(4), 1475-1490.
National Science Board (2014). *Science and Engineering Indicators 2014*. National Science Foundation: Arlington, VA. Retrieved from: https://www.nsf.gov/statistics/seind14/
Netcoh, S. (2017). Students' experiences with personalized learning: An examination using self-determination theory. Doctoral Dissertation, The University of Vermont.
Olson, S., & Riordan, D. G. (2012). Engage to excel: Producing one million additional college graduates with degrees in science, technology, engineering, and mathematics. Report to the President. *Executive Office of the President*.
Oz, E., & Kloser, M. (2021). Middle school students' motivational dispositions and STEM career attitudes. Paper presented at the 2021 Annual Meeting of the American Educational Research Association [Virtual Conference].
Perera, H. N., & McIlveen, P. (2018). Vocational interest profiles: Profile replicability and relations with the STEM major choice and the Big-Five. *Journal of Vocational Behavior*, 106, 84-100. https://doi.org/10.1016/j.jvb.2017.11.012
Patton, W., & Creed, P. A. (2001). Developmental issues in career maturity and career decision status. *The Career Development Quarterly*, *49*(4), 336-351. https://doi.org/10.1002/j.2161-0045.2001.tb00961.x
Potvin, P., & Hasni, A. (2014). Interest, motivation and attitude towards science and technology at K-12 levels: a systematic review of 12 years of educational research. *Studies in Science Education*, *50*(1), 85-129.
Ralston, C. A., Borgen, F. H., Rottinghaus, P. J., & Donnay, D. A. (2004). Specificity in interest measurement: Basic Interest Scales and major field of study. *Journal of Vocational Behavior*, *65*(2), 203-216. https://doi.org/10.1016/S0001-8791(03)00096-4
Renninger, K.A., & Schofield, L.S. (2014). Assessing STEM interest as a developmental motivational variable. Poster presented at Current Approaches to Interest Measurement, American Educational Research Association, Philadelphia, PA.
Renninger, K. A., & Su, S. (2012). Interest and its development. *Oxford handbook of motivation*, 167-187.
Roueche, J. E., & Baker III, G. A. (1987). *Access & Excellence: The Open-Door College*. AACJC Publications.
Rutschow, E.Z., & Schneider, E. (2011). *Unlocking the gate: What we know about improving developmental education*. MDRC Report. National Center for Postsecondary Research, Columbia University.
Saxe, G. B. (1988). Candy selling and math learning. *Educational researcher*, *17*(6), 14-21.
Schiefele, U., & Krapp, A. (1996). Topic interest and free recall of expository text. *Learning and individual differences*, *8*(2), 141-160.
Schraw, G., & Lehman, S. (2001). Situational interest: A review of the literature and directions for future research. *Educational psychology review*, *13*(1), 23-52.

Schwartz-Bloom, R. D., Halpin, M. J., & Reiter, J. P. (2011). Teaching high school chemistry in the context of pharmacology helps both teachers and students learn. *Journal of Chemical Education*, *88*(6), 744-750.

Snijders, T., & Bosker, R. (1999). *Multilevel analysis.* Sage.

Su, R., Tay, L., Liao, H. Y., Zhang, Q., & Rounds, J. (2019). Toward a dimensional model of vocational interests. *Journal of Applied Psychology*, *104*(5), 690.

Tang, M. (2009). Examining the application of Holland's theory to vocational interests and choices of Chinese college students. *Journal of Career Assessment*, *17*(1), 86-98. https://doi.org/10.1177/1069072708325743

Walkington, C., (2017). Design research on personalized problem-posing. In Galindo, E., & Newton, J., (Eds.) *Proceedings of the 39th annual meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education* (pp. 195-202). Indianapolis, IN: Hoosier Association of Mathematics Teacher Educators.

Walkington, C., & Bernacki, M. (2019). Personalizing Algebra to Students' Interests: How Student Funds of Knowledge Moderate Outcomes. *International Journal of Artificial Intelligence in Education*, *29*, 58-88. https://doi.org/10.1007/s40593-018-0168-1

Wang, M. T., Degol, J., & Ye, F. (2015). Math achievement is important, but task values are critical, too: Examining the intellectual and motivational factors leading to gender disparities in STEM careers. *Frontiers in Psychology*, *6*(36), 1-9.

Webb, R. M., Lubinski, D., & Benbow, C. P. (2002). Mathematically facile adolescents with math-science aspirations: New perspectives on their educational and vocational development. *Journal of Educational Psychology*, *94*(4), 785-794. https://doi.org/10.1037//0022-0663.94.4.785