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The Role of Mothers' Communication in Promoting Motivation for Math and Science Course-Taking in High School

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In the context of concerns about American youths' failure to take advanced math and science (MS) courses in high school, we examined mothers' communication with their adolescent about taking MS courses. At ninth grade, U.S. mothers (n = 130) were interviewed about their responses to hypothetical questions from their adolescent about the usefulness of algebra, geometry, calculus, biology, chemistry, and physics. Responses were coded for elaboration and making personal connections to the adolescent. The number of science, technology, engineering, and mathematics courses taken in 12th grade was obtained from school records. Mothers' use of personal connections predicted adolescents' MS interest and utility value, as well as actual MS course-taking. Parents can play an important role in motivating their adolescent to take MS courses.

In 2009, President Obama launched his Educate to Innovate campaign to promote excellence in science, technology, engineering, and mathematics (STEM) education. This is but one example of initiatives in many Western nations to encourage student interest and to close gender gaps in STEM; the VHTO, the Dutch national organization on girls and women in science and technology, is another example. In the United States, these initiatives are thought to be crucial to maintaining the nation's strength in scientific discovery and technological innovation (National Science Board, 2010). Many of these initiatives ask how a nation, community, school, or family can motivate youth to pursue STEM courses and careers. Most of the initiatives and research have focused on the role of schools in achieving these goals with adolescents (e.g., Beilock, Gunderson, Ramirez, & Levine, 2010; Hulleman & Harackiewicz, 2009; Yeager & Walton, 2011). We argue that parents are a largely untapped, and potentially powerful, resource for increasing students' STEM engagement (Harackiewicz, Rozek, Hulleman, & Hyde, 2012). In this article, we focus on the role of parents and, in particular, the role of mothers and their communications with their adolescent son or daughter about mathematics and the sciences. We consider how frequently mothers communicate about these topics, how skillful they might be in their communication about the value of STEM courses, and whether the communication variables are actually predictive, using a longitudinal design, of students' later interest in math and science (MS) and their actual course-taking in the senior year of high school.

The Importance of Motivating Students in Science and Mathematics

In the United States, substantial numbers of students do not take essential mathematics and science classes. For example, 10% of ninth graders

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take no mathematics and 18% take no science (National Science Foundation, 2014). These statistics vary strikingly as a function of parents' educational level. Among students whose parents had less than a high-school education, 18% took no mathematics in ninth grade, compared with 7% for those whose parents had a bachelor's degree. Moreover, high-school STEM courses are gateways to college STEM majors and, later, STEM careers. Therefore, in the research reported here, we focus on the important outcome of students' MS course-taking in 12th grade and factors that are linked to higher levels of course-taking.

A related concern is the gender gap in STEM. In the United States, the science and engineering workforce is largely White and male. Among those working in science and engineering occupations in 2010, 51% were White men, 18% were White women, 13% were Asian men, and 5% were Asian women, with smaller percentages for men and women from underrepresented minorities (National Science Foundation, 2013). This gender gap is foreshadowed by gender gaps in BA, MA, and PhD degrees earned, with women the most underrepresented in physics, computer sciences, and engineering, although they are not underrepresented at the BA level in biology or mathematics. Insofar as high school STEM courses are typically necessary for pursuing these majors at the university level, it is important to understand factors that may discourage or encourage girls, in particular, in taking STEM courses in high school.

Theoretical Framework

This research is rooted in expectancy-value theory and augmented with the parent socialization model, as well as Rogoff's theorizing about the importance of the social environment for children's thinking. According to expectancy-value theory, if a person is to take on a challenging task, such as taking physics in high school or majoring in engineering, she or he must (1) expect to succeed at the task and (2) value the task (Eccles-Parsons et al., 1983; Meece, Eccles-Parsons, Kaczala, Goff, & Futterman, 1982). Task value includes attainment value (how a task is related to one's identity), intrinsic value (interest in and enjoyment of the task), and utility value (UV, perceived usefulness of the task). The role of expectations for success in students' academic achievement and, in particular, their STEM achievement has been much studied and is well documented (e.g., Bleeker & Jacobs, 2004; Briley, Harden, & Tucker-Drob, 2014; Simpkins, Fredricks, & Eccles, 2015; Watt et al., 2012). Here we focus on the value side of the theory, which has been less studied. In addition, recent experimental work, described below, demonstrates the importance of UV in promoting academic outcomes. In particular, we focus on interest and UV as motivators of STEM course-taking, while still capturing one aspect of expectancies, mothers' perceptions of the adolescent's math ability.

The extant prior research, using both cross-sectional correlational designs and longitudinal designs, supports the hypothesis that perceived value, particularly intrinsic and UV, is related to STEM course-taking (e.g., Eccles, Barber, Updegraff, & O'Brien, 1998; Simpkins, Fredricks, & Eccles, 2012; Watt, 2005). For example, Wigfield (1993) found that students' math UV predicted intentions to enroll in more mathematics courses, above and beyond measures of mathematical ability and math self-concept. Similarly, in another study, math UV predicted the number of mathematics courses taken in high school, controlling for grade point average (GPA) and a measure of mathematical ability (Updegraff, Eccles, Barber, & O'Brien, 1996). Moreover, experimental research shows that, when students' perception of the UV of mathematics and science is increased, their course-taking increases (Harackiewicz et al., 2012; Rozek, Hyde, Svoboda, Hulleman, & Harackiewicz, 2015).

The parent socialization model extends expectancy-value theory to examine the crucial role of parents (Eccles, Freedman-Doan, Frome, Jacobs, & Yoon, 2000; Eccles-Parsons, Adler, & Kaczala, 1982). The model focuses on mechanisms such as parents serving as role models for their children and as socializers of their children's expectancies for success. There is much empirical support for the model. For example, in one study, mothers' estimates of their adolescent's ability to succeed in math-related careers significantly predicted career choices in MS in young adulthood (Bleeker & Jacobs, 2004). In another study, mothers' perceptions of their child's academic competence predicted the child's academic functioning (grades) a year later, but only for mothers who held entity theories of intelligence (Pomerantz & Dong, 2006).

The research is also rooted in Rogoff's (1990) theorizing that children's cognitive development is embedded in their social milieu, with parents being a crucial aspect of that milieu. According to this model, parents can support development by guiding children in problem solving and understanding new situations. This process has been called an apprenticeship in thinking. Although most research in the Rogoff tradition has studied children (e.g., Rogoff, Turkanis, & Bartlett, 2001; for an exception, see Love & Hamston, 2003), certainly this same kind of learning continues into adolescence, as does guidance from parents. In adolescence, youth still look to parents for guidance regarding educational choices, such as course-taking, which provides an opportunity for such guided interactions with parents. For example, when discussing which math course their son or daughter should take next, parents can elaborate on why the math class would be useful for their adolescent's future. This elaboration can be more or less specific, and can be more or less personal to their teen's interests and future goals. Both aspects of these discussions—the specific elaboration and the personal connection—can have an impact on the adolescent's perception of the value of math and thus have an impact on motivation for course-taking. Rogoff emphasized the importance of the adult's sensitivity in supporting learning; sensitivity involves expanding or elaborating contingently on the child's ideas, in finely tuned interactions. Related research in mathematics education has established the effectiveness of personalization in fostering students' learning (Cordova & Lepper, 1996; Walkington, 2013; Walkington, Petrosino, & Sherman, 2013).

The Role of Parents

Although some have questioned whether parents actually do influence their children (e.g., Harris, 1995, 1998; Robinson & Harris, 2014), the preponderance of evidence indicates that parents do indeed have an influence (Briley et al., 2014; Harackiewicz et al., 2012; Vandell, 2000). In particular, expectancy-value theory highlights the importance of socializers such as parents to children's developing expectancies for success and task values (Chhin, Bleeker, & Jacobs, 2008; Eccles, Jacobs, & Harold, 1990; Eccles et al., 1993), and, as noted earlier, the parent socialization model expands on the nature of these influences.

Although research on links between parents' self-reported beliefs and children's academic beliefs and performance is extensive, only a handful of studies have examined parents' actual behaviors in relation to their children's academic outcomes. For example, in one study mothers' recorded science talk with their 9-year-olds predicted the child's reading comprehension for a science text 2 years later (Tenenbaum, Snow, Roach, & Kurland, 2005). Simpkins et al. (2012) found that several self-reported maternal behaviors (modeling, encouragement, provision of materials, and coactivity) mediated the relationship between mothers' and youths' beliefs and math course-taking; nonetheless, self-reports of behaviors are not the same as actual observations of behaviors. Huntsinger and colleagues have conducted studies designed to get at parents' behaviors in relation to their children's mathematics learning (Huntsinger & Jose, 2009; Huntsinger, Jose, Liaw, & Ching, 1997). As an example, in one study they interviewed Euro-American, Chinese-American, and Taiwan-Chinese mothers and fathers about how they facilitated their preschool or kindergarten child's development in mathematics (Huntsinger et al., 1997). The results indicated that, compared with the Euro-American parents, the Chinese-American parents gave more direct, formal mathematics instruction to their children, structured more time for mathematics practice, and encouraged their children more in mathematics-related activities. The amount of time that the child spent on math-related activities was derived from time diaries completed by the parents. The results showed that a combination of the amount of parents' teaching children and the child's time spent in math practice significantly predicted the child's tested math skills. Notably, none of these studies explicitly assessed parents' ability to communicate about the UV of mathematics and science classes with their child.

In a meta-analysis of links between parental involvement and middle-school youths' achievement, many types of involvement were assessed across the studies that were reviewed (Hill & Tyson, 2009). These included measures such as PTO involvement and checking homework. Only a small number of studies examined discussions between parents and youth about school, and specifically about choice of activities in school. Notably, the National Education Longitudinal Study obtained both parents' and youths' reports of variables such as discussions about high school and planning high-school programs. Several researchers have used these measures to predict academic outcomes (e.g., Desimone, 1999; Muller, 1995; Sui-Chi & Willms, 1996). In the Hill and Tyson (2009) meta-analysis, the correlation between overall parental involvement and academic achievement was only $r = .04$; however, the correlation between parents' academic socialization behaviors (e.g., communicating about the value of education, encouraging educational and occupational aspirations) and youths' academic achievement was $r = .39$, pointing to the importance of this particular category of parents' behaviors.

A more recent meta-analysis also examined the role of parental involvement in students' academic achievement in primary and secondary school (Castro et al., 2015). The two largest correlations between parental involvement and academic achievement were parental expectations (z = 0.22) and communication with children about school issues (z = 0.20). The first effect speaks to parental socialization on the expectancy side of the expectancy-value model. The latter effect concerns parents' communications, broadly defined, and those communications are the topic of the current study.

Overall, then, past research, based on meta-analytic syntheses, indicates that parents' communications with their children about school issues are important and linked to students' academic achievement (Castro et al., 2015; Hill & Tyson, 2009). However, there is a paucity of research examining the nature of parents' communications and behavior with their children, particularly in regard to mathematics and science, and no studies have assessed parents' communications about the UV of mathematics and science.

Following from Rogoff's theory, if parents are to be effective at guiding their children's STEM course participation they must be able to elaborate answers in response to their children's statements about those courses, and they must display sensitivity by tailoring their response to the individual child. To capture these elements, we coded the extent of elaboration and personal connections that mothers displayed in response to hypothetical questions from their adolescent about the usefulness or UV of MS classes in high school. As noted earlier, research in mathematics education has established the effectiveness of personalization in fostering students' learning (Cordova & Lepper, 1996; Walkington, 2013; Walkington et al., 2013).

To our knowledge, this is the first study to capture parents' responses about these topics with adolescents.

The Current Study

The current study is embedded within a long-term longitudinal study, the Wisconsin Study of Families and Work (WSFW), which began in 1990–1991, when pregnant women were recruited for participation. The families were then followed until that child finished high school. The current study focuses on the adolescent years, using data collected from seventh grade through 12th grade.

As noted earlier, no prior research has examined parents' capacity to guide their adolescent's MS participation by providing sensitive and elaborated communications to their adolescent. We address this lacuna with data from interviews with mothers concerning the usefulness of math, biology, chemistry, and physics classes for their high-school student, in response to a hypothetical questioning of their usefulness from the adolescent. (We interviewed fathers as well but, despite our best efforts, the response rate was low. We therefore focus just on mothers here.) The interviews were conducted in the summer after ninth grade and were coded for both elaboration and personal connections to measure sensitivity. Later, in 10th grade, we obtained brief measures of the adolescents' interest and perceptions of the UV of MS courses, along with the mother's estimate of the frequency of mother–child conversations about these topics. At the end of 12th grade, we obtained high-school transcripts to derive an objective measure of the number of MS classes the adolescent had actually taken.

We ask the following questions. How capable are mothers at elaborating the usefulness of algebra, geometry, calculus, biology, chemistry, and physics to their adolescent? How well do mothers provide guidance, as evidenced by elaboration and by personalizing the communication to their child? Do elaboration and making personal connections work in different ways in their impact on adolescents' interests, perceptions of UV, and course-taking? Do mothers talk differently about these topics with daughters compared with sons? How frequently do mothers have conversations on these topics with their children? And finally, can these communication variables predict adolescents' later perceptions of the UV of and interest in STEM courses and, in turn, their actual enrollment in these courses in 12th grade?

To address this last question, structural equation modeling (SEM) was used to test a model in which the number of MS classes taken in 12th grade is predicted by mothers' estimate of the child's math ability, the mother's elaboration and personalization of the usefulness of MS for her child, the number of mother–child conversations about MS classes, and the adolescent's interest in and perceived UV of MS classes (Figure 1). Mother's education is included in the model because mother's education is a powerful predictor of children's academic performance (Melhuish et al., 2008) and because mother's level of education should be linked to her capacity to generate elaborated responses about the usefulness of MS

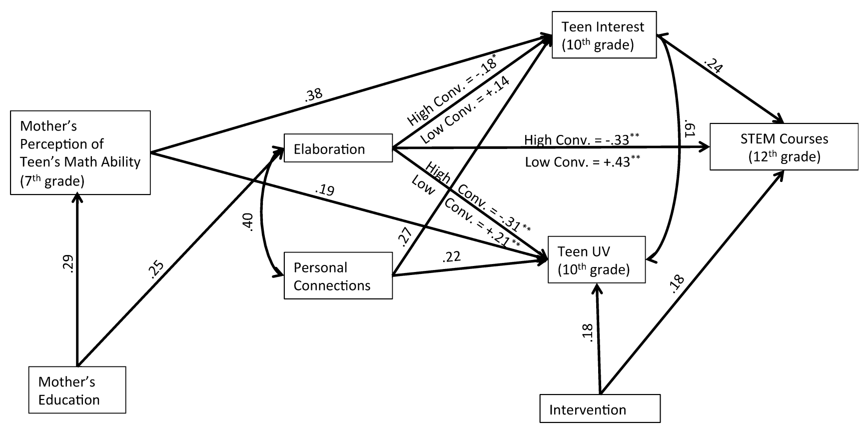

FIGURE 1 Empirical path model in which communication variables predict adolescents' interest, utility value, and math and science courses taken in 12th grade. Adolescent's gender was included as a covariate for all variables. Only significant paths are shown. All effects are standardized coefficients except for the interaction effects, which are unstandardized.

courses. Mother's perception of the adolescent's math ability, measured in seventh grade, is also included because it is a well-documented predictor of children's academic outcomes (e.g., Bleeker & Jacobs, 2004).

METHODS

Participants

The sample comprised families participating in the longitudinal WSFW (for details of recruitment, see Hyde, Klein, Essex, & Clark, 1995). At the time of original recruitment before the child was born, in 1991, 78% of the sample was from the Milwaukee Standard Metropolitan Statistical Area (SMSA) and the remaining 22% was from the Madison SMSA. Mothers' education ranged from 12 to 20 years, with a mean of 15.5 years (SD = 2.01) on a scale where 12 years is equivalent to a high-school diploma or GED completion.

The current sample consisted of 130 adolescents (63 girls, 67 boys), who attended ninth grade in the 2006–2007 academic year, and their mothers. Regarding ethnicity, 90.8% of the adolescents were White, 3.8% were African American, 0.8% were Hispanic, 3.8% were American Indian, 0.8% were Asian American, and 6.2% were biracial or multiracial. Although we recruited in Milwaukee County with the goal of increasing the ethnic diversity of the sample, two collaborations with minority-serving clinics fell through, yielding a sample that overrepresents Whites. Adolescents attended 108 different high schools. At the time of 12th-grade data collection, the mean age of participants was 18.7 (SD = 0.22).

Procedure

At the end of ninth grade (June 2007), mothers were interviewed by phone about the utility of six STEM subjects: algebra, geometry, calculus, biology, chemistry, and physics. Mothers were asked how they would talk with their teen about the usefulness of the topics. Specifically, they were asked to respond to the following hypothetical situation: "Imagine that [teen's name] comes home from school and says to you, '[Subject] is such a waste of time'. What would you say in response?" The question was repeated for each subject, and the interviews were transcribed for later coding. The questions were posed in an open-ended format to determine what mothers could actually produce for answers, rather than simply asking them to recognize good answers or rate how useful they thought a class might be. In total, 136 mothers were interviewed. However, six participants were excluded from analyses because they did not complete the conversations interview or did not answer a majority of the interview questions, leaving 130 mother–adolescent pairs in the analyses reported here.

Questionnaire data were collected from mothers and from adolescents in the summer following 10th grade. At the end of 12th grade, high-school transcripts were collected from the students' schools and were coded for STEM course-taking. In addition, because this study was embedded within a larger longitudinal project, a measure of the mother's perception of the adolescent's mathematical ability was available from seventh grade.

Starting in October 2007 (10th grade), an intervention designed to increase parental knowledge regarding STEM UV was administered to approximately half the participants (for more details, see Harackiewicz et al., 2012). Intervention materials identified potential connections between STEM fields and adolescents' current and future goals, as well as techniques for parents to use in communicating with their adolescent. The intervention materials consisted of a brochure mailed to parents in 10th grade, a second brochure mailed to parents in 11th grade, and a dedicated website made available in spring of 11th grade. Families were randomly assigned to the intervention group or a control group. The current article is not concerned with the intervention (which occurred after the interviews were conducted) and therefore the intervention is treated as a control variable.

Measures

Communication measures. Three variables assessed mother–child communication about STEM: number of conversations, elaboration of UV, and personal connections about UV.

The number of conversations that the mother had with her child regarding the UV of MS classes was self-reported by the mother in the summer after 10th grade. Two questions were used: "Since the start of 10th grade, how often have you had conversations with your teen about the usefulness of math classes?" and "Since the start of 10th grade, how often have you had conversations with your teen about the usefulness of science classes?" Response options were 0 conversations, 1–2 conversations, or 3 or more conversations. These two items were averaged to create an overall measure of number of STEM conversations (α = .80).

As noted earlier, the mother's tendencies to elaborate and respond sensitively to her child were assessed at the end of ninth grade with the following question: "Imagine that [teen's name] comes home from school and says to you, '[Subject] is such a waste of time'. What would you say in response?" with the question repeated for each STEM topic (algebra, geometry, calculus, biology, chemistry, and physics). Mothers' responses were then subjected to content analysis.

The *elaboration* measure assessed the depth and detail of the mother's communication about the UV of each topic. It was coded as 1 of 4 levels (see Table 1 for examples): *none* (mother did not generate a response), *useful nonspecific* (mother described value without referring to specific examples), *useful specific* (mother described value with specific examples), and *useful specific and elaborated* (mother described value elaborately and with specific examples). Responses concerning each STEM topic were coded separately by two independent coders (interrater reliability of 86%, discrepancies resolved by consensus) and then added together to create an overall elaboration score (α = .74).

TABLE 1
Categories Used in Coding Elaboration

	Definition	*Examples*
Level 0	Mother gave no response	
Level 1	Useful nonspecific	It will be important for her career and her future classes
		You're always going to use math in your daily life
Level 2	Useful specific	I think I'd have to talk to her about something I would know about chemistry, which would be organic chemistry or baking, and how you use chemistry in everyday life
		Biology is a foundation for a lot of different science, and especially behavioral sciences as well as other kinds of sciences
Level 3	Useful specific and elaborated	My neighbor is building a shed, wondering how much weight could this hold, whether a 2 × 4 or a 4 × 4. They had all these measurements because he's building it himself. And he was working on it and all that construction stuff relates to it
		Since I'm a carpenter, I demonstrated the importance of using trigonometry on laying out roof structures for houses and buildings using triangular shapes

Following in the Rogoff tradition, the extent to which a mother made *personal connections* to her child's life when explaining the value of each topic was used as a measure of sensitivity of communication. It was measured by a count of the number of examples using personal references to the child, across STEM subjects (interrater correlation was r = .84). Most often, the mother referred to ways in which MS had value for the adolescent's career, everyday life, past experiences, interests, or ability in the topic. Examples of personalization included, "She does construction projects with her dad, and they'll use algebra to calculate different things. And they'll use different math concepts in their project. And so I would probably remind her of when she's used that," and "Most likely you're going to be in some sort of science field, and you're going to need to have had calculus."

In addition, for descriptive purposes, the personal connections offered by mothers were coded as to the type of personal connection and whether the mother related usefulness to (1) the adolescent's desired *career* (e.g., "She's definitely going to need biology, she's interested in going into the health field, that's definitely a requirement"), (2) *everyday life*, relating the value of the subject to its use in everyday activities or as general knowledge (e.g., "Angles, things when you're going to paint your room desk. Might help us to know the right corners and angles and measurements and square footage. Stuff like that will help you in your everyday life"); (3) *ability*, relating the value of the subject to the adolescent's ability or talent in the subject ("I would try to push him into sciences and math because I think he's good at it. And he probably would do good in it"); (4) *past experiences*, relating the value of the subject to something the adolescent has experienced in the past (e.g., "And actually when he was a little kid we used to talk about this, how baking is chemistry, baking is science. So, I would go right back to 'Hmm, remember when you were eight and we had this conversation.'"); or (5) intrinsic value or *interests* (e.g., "Physics is a lot of math, he likes math, and they build on each other").

Mother's perception of adolescent's math ability. The mother's perception of her child's math ability was measured when the adolescent was in seventh grade, with the following three items originated by Eccles (Frome & Eccles, 1998): "How good is your child at math?", "How good is your child at math, compared to other kids?", and "How much natural talent does your child have in math?" Each was rated on a tailored 1–7 scale and items were averaged ($\alpha = .92$).

Adolescent's STEM interest and UV. In the summer following 10th grade, we collected brief measures of the adolescent's *interest* in five STEM topics (algebra, geometry, biology, chemistry, and physics), with one item per subject ("I think [topic] is interesting."). Each item was rated on a 1–5 scale (*strongly disagree–strongly agree*) and ratings were averaged.

The adolescent's perception of the *UV* of five STEM topics (algebra, geometry, biology, chemistry, and physics) was measured with one item per subject ("In general, how useful is what you learn in [topic]?"). Each item was rated on a 1–7 scale (*not very useful–very useful*) and the items were averaged to form the measure of STEM UV.

Cronbach's alpha was computed for both the interest and the UV scales across all five STEM topics. The items about biology, however, decreased internal consistency, meaning that interest in biology did not correlate well with interest in the other topics. This may have occurred because biology is generally not as mathematical as chemistry and physics. After removal of the biology item from each scale, $\alpha = .78$ for interest and .86 for UV.

STEM courses taken. High-school transcripts were obtained for 123 (61 girls, 62 boys) of the 130 students, who attended 108 different high schools. (Transcripts were missing in cases such as home schooling.) We coded transcripts for the number of semesters of mathematics and science taken during 12th grade. Mathematics and science courses are more likely to be optional and a matter of choice in 12th grade, by comparison with earlier grades, when they are more likely to be required. Thus, this 12th grade measure should be sensitive to students' STEM motivation. All transcripts were coded independently by two coders with an interrater reliability of 95%. In the case of disagreement about the STEM content of the courses, the schools' websites and course descriptions were consulted and disagreements were resolved by consensus.

RESULTS

Descriptive Analyses

Zero-order correlations and descriptive statistics for major variables are shown in Table 2. For number of conversations, 13% of mothers reported that they did not have any conversations with their child about the usefulness of math classes during 10th grade and 15.3% did not have any conversations about science classes. Approximately 41% of mothers reported having 1–2 such conversations about math classes (44% about science classes) and 46% reported having three or more utility conversations about math classes (41% about science classes). Number of conversations about math or science did not differ by adolescent's gender, $t(128) = .46$, $p = .65$.

The degree to which mothers gave elaborated responses in their interviews differed by STEM course (see Table 3). Mothers gave the most elaborated responses for biology ($M = 1.45$, $SD = 0.88$) and chemistry ($M = 1.38$, $SD = 1.01$) and the least elaborated responses for physics ($M = 0.86$, $SD = 0.95$) and calculus ($M = 0.70$, $SD = 0.76$).

TABLE 2
Zero-Order Correlations and Descriptive Statistics for Major Variables

Variable	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*
1. Mothers' education	–							
2. Mothers' perception of teens' math ability	0.29**	–						
3. Number of conversations	0.10	0.05	–					
4. Personal connections	0.20*	0.19*	0.17*	–				
5. Elaboration	0.32**	0.18*	0.19*	0.43**	–			
6. Teen interest (10th grade)	0.09	0.40**	−0.07	0.28**	0.10	–		
7. Teen UV (10th grade)	0.09	0.20*	0.03	0.20*	0.05	0.65**	–	
8. STEM courses (12th grade)	0.13	0.17	−0.01	0.16	0.17	0.27**	0.22*	–
Boys *M* (*SD*)	15.21 (1.80)	5.52 (1.15)	1.28 (0.61)	2.22 (1.22)	6.69 (3.52)	3.23 (1.12)	4.62 (1.52)	3.36 (1.70)
Girls *M* (*SD*)	15.60 (2.33)	5.37 (1.11)	1.33 (0.65)	2.59 (1.42)	6.60 (3.71)	3.10 (1.02)	4.51 (1.36)	3.73 (1.82)
d	−0.19	0.13	−0.08	−0.28	0.02	0.12	0.08	−0.21

Note. UV = utility value. None of the mean gender differences were significant. d is computed as the mean for males minus the mean for females divided by the within-groups SD. Therefore, positive values reflect higher scores for boys.
$^*p < .05$; $^{**}p < .01$.

Elaboration scores did not differ by adolescent's gender $t(128) = .13$, $p = .90$.

Overall, 62.3% of mothers made at least one personal connection, and on average, mothers made 2.4 connections across the entire interview. Of these personal connections, 33.9% were everyday examples, 32% were connections to the adolescent's intended career, 17.7% were related to the adolescent's interests, 9.4% were connections to past experiences, and 7.2% were connections to the adolescent's ability (see Figure 2). There were no gender differences in the frequency of personal connections for any of these categories, with one exception. Connections to past experiences were more likely to be articulated for girls (19%) than boys (8%), χ^2 (1, $N = 130$) = 3.83, $p = .05$.

On average, students chose to take approximately 3.54 ($SD = 0.95$) STEM courses during the 12th grade. Of these STEM courses, 53.4% were math and 46.6% were science courses. Approximately 35.8% of students took physics, 30.9% took precalculus, 26.0% took calculus, 23.6% took biology (including human anatomy and physiology, microbiology, and marine biology), and 16.3% took statistics (see Table 4). Other courses included advanced algebra, trigonometry, environmental science, earth science, and chemistry.

Overview of SEM Analyses

We used structural equation modeling in Mplus (Version 7.3; Muthén & Muthén, 1998–2012) with maximum-likelihood estimation to examine the processes by which adolescent's gender (coded 0 for females and +1 for males), mother's education, mother's perception of adolescent's math ability, number of UV conversations, personal connections, elaboration, and the intervention (coded 0 for control and +1 for treatment) predicted adolescents' interest and UV in 10th grade, and STEM course-taking in 12th grade. Mother's education and mother's perception of adolescent's math ability were used to predict the conversation variables (i.e., number of UV conversations, personal connections, and elaboration). All two-way and three-way interactions were computed and nonsignificant interactions were trimmed from the model. Structural paths that were nonsignificant were set to zero to achieve the final model (see Figure 1). Adolescent's gender was included as a covariate for all variables. Cases with missing data were included by using full information maximum-likelihood methods (Arbuckle, 1996).

The comparative fit index (CFI) and the root-mean-square error of approximation (RMSEA)

TABLE 3
Distribution of Elaboration Scores

Elaboration	*Algebra (%)*	*Geometry (%)*	*Biology (%)*	*Chemistry (%)*	*Physics (%)*	*Calculus (%)*
None	24.6	28.5	15.4	22.3	44.6	46.5
Useful, nonspecific	50.8	40.0	35.4	33.1	32.3	38.8
Useful, specific	15.4	17.7	38.5	28.5	15.4	13.2
Useful, specific and elaborated	9.2	13.8	10.8	16.2	7.7	1.6
M (*SD*)	1.09 (0.88)	1.17 (1.00)	1.45 (0.88)	1.38 (1.01)	0.86 (0.95)	0.70 (0.76)

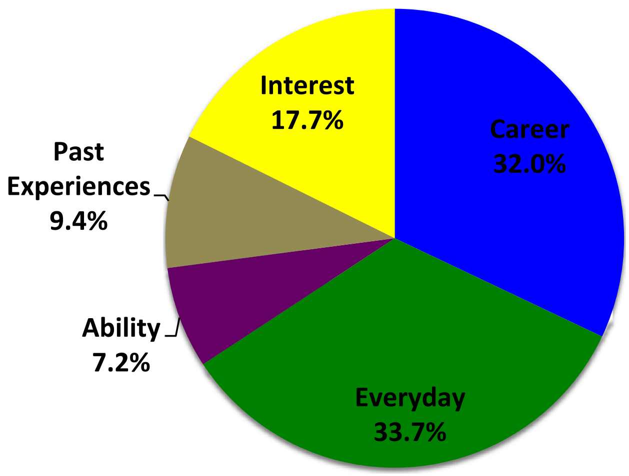

FIGURE 2 Distribution of personal connections made by mothers.

TABLE 4
Percentage of Students Who Took Math and Science Courses in 12th Grade

Math Courses (%)		*Science Courses (%)*	
Precalculus	30.9	Physics	35.8
Calculus	26.0	Biology	23.6
Statistics	16.3	Other science	12.2
Advanced algebra	12.2	Environmental science	5.7
Trigonometry	9.8	Earth science	5.7
Other math	8.1	Chemistry	4.1

Note. AP and IB courses are included in these numbers.

were the primary criteria used to determine that the model exhibited satisfactory fit ($\chi^2 = 26.31$, $df = 22$, RMSEA = 0.039, CFI = 0.98). CFI values greater than 0.95 and RMSEA values of less than 0.06 are typically needed before it can be concluded that there is a good fit between the model and the observed data (Hu & Bentler, 1999). Overall, the model accounted for 18.2% of the variance in 12th-grade STEM course-taking, 14.1% of the variance in 10th-grade perceived UV, 24.4% of the variance in 10th-grade interest, 6.3% of the variance in elaboration, and 9.3% of the variance in mothers' perception of adolescents' math ability. (Because variance in the personal connections variable was not significantly predicted in the model, paths predicting it were set to 0.)

Effects on Perception of Adolescents' Math Ability in Seventh Grade

Mothers' years of education significantly predicted mothers' perception of adolescents' math ability in seventh grade ($z = 3.74$, $p < .001$, $\beta = .30$), such that more years of education were associated with higher perceptions of adolescents' math ability.

Effects on Number of Conversations, Personal Connections, and Elaboration

Neither mothers' years of education nor mothers' perception of adolescents' math ability predicted number of conversations between mothers and adolescents or personal connections articulated in the interviews. Mothers' education was a significant predictor of elaboration ($z = 3.20$, $p = .001$, $\beta = .25$), such that mothers with more years of education generated more elaborated responses in their interview.

Effects on Adolescents' Interest

Mothers' perception of adolescents' math ability was a significant predictor of adolescents' STEM interest ($z = 5.03$, $p < .001$, $\beta = .38$), such that mothers' higher perceptions of adolescents' math ability in seventh grade positively predicted their adolescents' STEM interest at the end of 10th grade. Personal connections were a positive significant predictor of adolescents' STEM interest ($z = 3.20$, $p < .001$, $\beta = .28$) with more personal connections being related to higher levels of adolescent interest. There was a significant interaction between number of conversations and elaboration ($z = -1.96$, $p = .05$, $\beta = -.15$), such that the highest level of

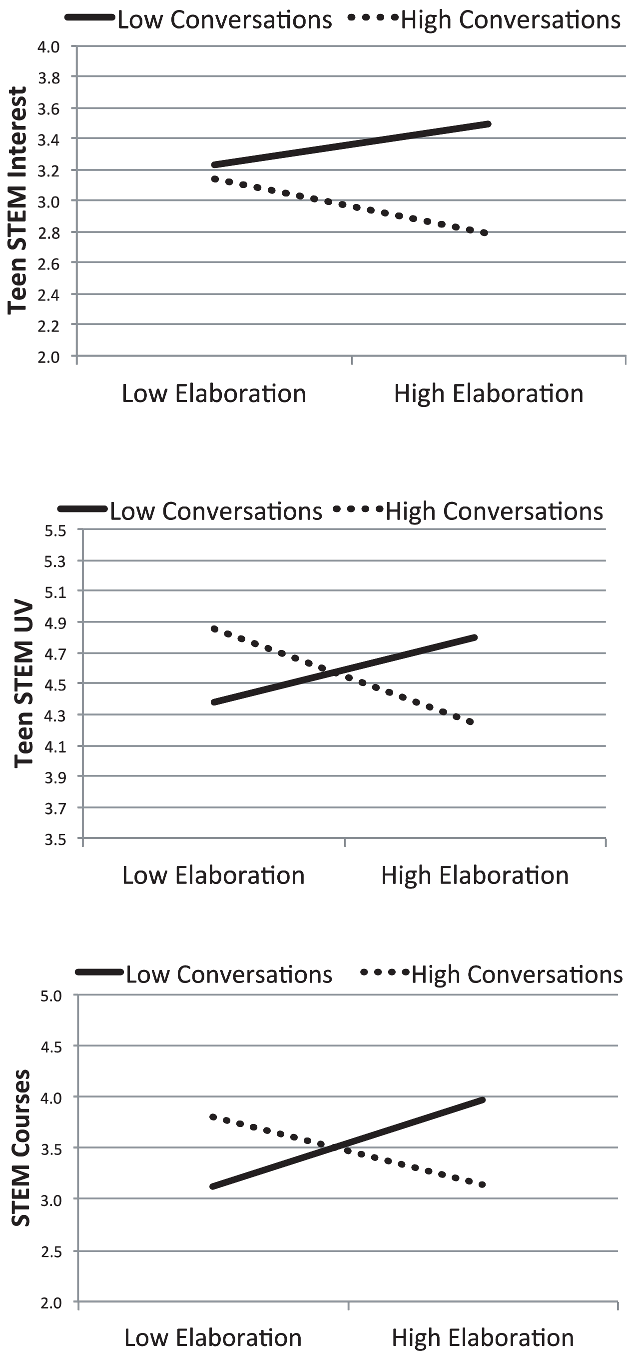

FIGURE 3 The interaction between level of mother's elaboration and number of science, technology, engineering, and mathematics (STEM) conversations, predicting adolescents' STEM interest, utility value, and course-taking.

interest occurred with high elaboration and few conversations (Figure 3).

Effects on Adolescents' UV

Mothers' perception of adolescents' math ability was a significant predictor of adolescents' UV ($z = 2.24$, $p = .03$, $\beta = .19$), such that mothers' higher perceptions of adolescents' math ability in seventh grade predicted higher levels of their adolescents' UV at the end of 10th grade. Personal connections articulated in the interview also significantly predicted adolescents' UV ($z = 2.52$, $p = .01$, $\beta = .23$), with more personal connections made in the interview being related to higher levels of adolescent UV. There was a significant interaction between elaboration and number of conversations ($z = -2.34$, $p = .02$, $\beta = -.19$), such that the highest levels of UV occurred either with high elaboration and few conversations, or with low elaboration and many conversations (Figure 3). Finally, there was a significant effect of the experimental intervention on adolescent UV ($z = 2.68$, $p = .007$, $\beta = .18$), such that adolescents whose parents received the intervention reported more UV in 10th grade than those whose parents were in the control group.

Adolescents' STEM Course-Taking in 12th Grade

Adolescents' interest in 10th grade significantly predicted STEM course-taking in 12th grade ($z = 2.92$, $p = .004$, $\beta = .24$), such that higher levels of interest in 10th grade predicted more STEM courses taken in 12th grade. There was a significant interaction between elaboration and number of conversations ($z = -2.96$, $p = .003$, $\beta = -.24$) such that the highest levels of course-taking were achieved either with the combination of high elaboration and fewer conversations, or less elaboration but more conversations (Figure 3). There was a nearly significant gender difference in STEM course-taking ($z = -1.85$, $p = .06$, $\beta = -.15$) such that girls tended to take more STEM courses than boys. There was a significant effect of the experimental intervention on course-taking ($z = 2.13$, $p = .03$, $\beta = .18$), such that adolescents whose parents received the intervention took more MS in 12th grade, compared with controls (see Harackiewicz et al., 2012; Rozek et al., 2015). In addition, using procedures described by Preacher and Hayes (2008), we found an indirect effect of personal connections on STEM course-taking through adolescent's interest, $z = 2.13$, $p = .03$.

DISCUSSION

The overall goal of the research reported here was to investigate mothers' communication with their adolescent regarding science and math classes in high school. The research probed whether multiple aspects of these communications would predict the adolescent's later interest in and perception of the UV of MS classes and, in turn, actually taking MS classes in 12th grade.

The results indicated that mothers vary considerably in their ability to respond—in terms of elaboration and making personal connections for the adolescent—to hypothetical questions from the adolescent about the usefulness of MS classes. Overall, 75% of mothers provided at least some elaboration about algebra, although most did it at the simplest level, and 85% elaborated at least somewhat about the usefulness of biology. For physics, however, only 53% elaborated. Like current students, many of these mothers probably never took physics in high school, and it is difficult to elaborate on the usefulness of a topic that one has never studied. Indeed, mothers with more education were more capable of elaboration about the importance of STEM classes. The limited capacity of many mothers to elaborate on the UV of STEM classes means that mothers could be a fruitful point of intervention.

In the structural equation modeling, the communication variables did predict adolescents' interest in and perceptions of the UV of MS courses; and elaboration, in interaction with number of conversations, predicted the number of MS classes that they took in 12th grade. Overall, we were able to predict 18.2% of the variance in STEM course-taking using the variables specified in Figure 1. Nonetheless, structural equation modeling revealed more complex patterns and interactions among variables.

The interaction between number of mother–child conversations and the mother's score on elaboration about STEM, predicting number of STEM courses, was not in the expected direction (Figure 3). Intuitively, one might expect number of conversations always to be a positive predictor and greater elaboration always to be a positive predictor of STEM courses taken. In addition, we might expect that one communication variable would potentiate the other, so that the greatest STEM course-taking would occur with the combination of many conversations and much elaboration. Yet that is not what the data indicate. Instead, the highest levels of STEM course-taking occurred either with many conversations but less elaboration, or fewer conversations but much elaboration. First, we note limitations on the interpretation of the interaction, based on how and when the variables were measured. The elaboration measure was based on mothers' responses to hypothetical questions from their adolescent, not on actual interactions in which the adolescent posed such questions. Moreover, the elaboration measure was obtained in the summer before 10th grade, and the measure of number of conversations was obtained at the end of 10th grade, reporting on the past year.

With these caveats in mind, we offer two possible interpretations of the interaction, one based on the concept of reactance and the other based on laboratory research on optimal sources of UV information. The social–psychological concept of reactance (Brehm & Brehm, 1981) is based on the principle that people desire free choice in their behaviors. If external factors constrain that freedom of choice, the person reacts to restore freedom, often by behaving in a manner that is opposite to what the external source is pressing for. In a recent paper, Van Petegem and colleagues argued that a controlling parenting style creates reactance in adolescents (Van Petegem, Soenens, Vansteenkiste, & Beyers, 2015). Their data, across several studies, supported this hypothesis and, in particular, supported it for an academic outcome, intention to study more.

Applying the concept of psychological reactance to the current study, it may be that a combination of extensive elaboration and many conversations stimulates reactance in the adolescent. More moderate levels of communication—for example, much elaboration but fewer conversations—appear to yield optimal results. Consistent with these ideas, social psychologists, in their intervention studies, have noted that it is very difficult to tell an adolescent why she or he should value learning and have the communication be effective (Hulleman, Godes, Hendricks, & Harackiewicz, 2010; Hulleman & Harackiewicz, 2009; Yeager et al., 2014). They note the problem of reactance and conclude that it is more effective to encourage adolescents to develop their own ideas about UV and formulate their own goals; adults can provide guidance in this process but cannot dictate the motivation or goals. Moreover, autonomy is a crucial developmental issue for adolescents; indeed, it often warrants an entire chapter in textbooks on adolescent development (e.g., Steinberg, 2013). With autonomy-seeking adolescents, reactance may occur when parents engage in numerous, highly elaborated communications about the UV of MS classes.

It is worth noting that these findings and the process of reactance may be specific to the United States and other independence-oriented cultures. In interdependent cultures, such as traditional East Asian and Asian American cultures, parents are quite directive about school matters (e.g., Huntsinger et al., 1997), the culture expects this approach, and children seem to respect it rather than showing reactance.

A second possible interpretation is based on related laboratory studies showing that UV communicated by an outside source (compared with self-generated ideas about UV) can decrease interest and performance for students who lack confidence (Canning & Harackiewicz, 2015; Durik, Schechter, Noh, Rozek, & Harackiewicz, 2015). Anxiety, for example, may be a factor if students are told that science is important yet they believe they are not good at it. Their interest may then decrease to protect against the anxiety. This line of research suggests that, for parents to increase their adolescent's appreciation of the UV of STEM courses, it may be even more helpful to have the adolescent generate ideas about UV themselves, especially for adolescents who lack confidence (Hulleman & Harackiewicz, 2009).

One of the most important findings was that mothers' scores on personal connections directly predicted adolescents' interest and STEM UV measured in 10th grade. Moreover, mothers' scores on personal connections had an indirect effect on STEM course-taking through the variable of adolescent's interest. These findings are consistent with research on the effectiveness of personalization in mathematics instruction in the schools (Walkington et al., 2013). Making personal connections can become a powerful tool for parents in their communications with their children about school. Moreover, any parent can use personalization, even if they have not taken the relevant class and cannot elaborate about its usefulness. The effect of personal connections demonstrates how important parents can be. Parents may even be more effective than teachers at making personal connections, because parents have much more detailed knowledge of their own child's interests, experiences, and aspirations.

The content of the personal connections that mothers made (Figure 2) indicates that the most common themes relate to the everyday usefulness of material from a class and the importance of the material for the adolescent's intended career. Connections to the adolescent's personal interests were also common. Less frequently, mothers made connections to the adolescent's ability or talent and to the adolescent's past experiences. Many mothers were quite adept at making these personal connections. One mother used interests, past experiences, and career.

> I would remind her of her interest in physical therapy and how important geometry is for understanding the human body. I'd also point out to her how important it is in her dancing. And, she has one instructor that she thinks the world of who is very scientific in his explanations of how the human body works and how the choreography works. And it is geometry, it really is. So, then when you make a practical application out of it, it's much more interesting for her.

Another mother used interests, everyday life, and career.

> She loves animals. So I think, just that it would help you understand animals, living things, or just help you about our own bodies, humans, and just living things. So it's very... I can see a lot of application in everyday life. And maybe if you want to be a veterinary assistant that it could be a real help in your career. That class she's looking forward to.

These findings provide additional insights into the mechanisms by which parents' socialization practices influence their children's interests, perceptions of UV, and academic course choice, as specified in expectancy-value theory and the parent socialization model. Specifically, parents' socialization practices can be particularly effective if parents use personal connections when explaining the usefulness or UV of classes.

Whereas the findings indicate that personal connections operate in a direct, positive manner on both adolescents' STEM interest and perceptions of UV, elaboration functioned differently. Elaboration operated in a more complex way and may actually be counterproductive in the context of a high number of conversations with the adolescent, although it may be quite effective when paired with fewer conversations.

Gender Differences and Similarities

In light of the gender gap in some STEM fields, one of the goals of this study was to determine whether there were subtle differences in mothers' treatment of girls compared with boys, which might contribute to the gender gap. The answers were perhaps surprising. Mothers did not generate more elaborated responses to sons than to daughters, nor was there a gender difference in making personal connections (with one exception, discussed below). Neither did mothers of sons report more conversations about STEM courses than mothers of daughters. These findings may reflect trends of parents today to treat their daughters and sons in a more equitable manner than parents did in previous generations (Epstein & Ward, 2011). Another possibility is that gender-differentiated treatment was not evident because the situation was hypothetical; perhaps, when actually talking with a son or daughter, mothers would give more gender-differentiated responses.

One exception to the pattern of gender similarities in mothers' treatment of their sons and daughters was in one aspect of the personal connections variable. Mothers' articulation of personal connections to past experiences was more likely for girls (71%) than for boys (29%). However, there were no gender differences in the other categories of personalization, so it appears that neither boys nor girls receive substantially better personalization overall. Taken together, then, the results of the current study provide no evidence of gender-differentiated behavior of mothers in the domain of STEM, nor does it suggest that mothers contribute in a major way to gender gaps in STEM occupations.

Strengths and Limitations

The longitudinal design—in which variables measured in seventh and ninth grade predicted adolescents' interest and perceptions of UV in 10th grade and courses taken in 12th grade—is a strength. In addition, data came from multiple sources—mothers' reports, adolescents' reports, and school records—rather than from a single informant.

It should be noted that the measures of elaboration and personal connections in mothers' communication were based on interviews with mothers about how they would talk with their child in response to hypothetical statements from the child, rather than on actual conversations. An important next step in research will be an analysis of actual conversations between mothers and adolescents on the topic of STEM. Yet the approach of the hypothetical questions posed here has the strength of standardizing the statement from the adolescent to which each mother responded. In live dyadic interactions, it would be more difficult to capture the precise elements of mothers' responses that were elicited in the current study.

One limitation is the ethnic composition of the sample, which was 91% White; therefore, the findings cannot be generalized to ethnic minority populations. Because there are instances in psychological research where phenomena found in White populations do not generalize to ethnic minority populations (e.g., Kling, Hyde, Showers, & Buswell, 1999), future research should study mother–adolescent communication about the value of STEM classes in these populations. A second limitation is that the parents' average level of education was higher than the national average. More research is needed with families in which the parents are less educated. As noted earlier, mother's education is one of the best predictors of children's mathematics performance (Melhuish et al., 2008), and in our research, mothers' education was correlated with the quality of their elaboration of UV. These findings suggest that patterns of findings might differ in populations with lower parental education and that the findings might be even stronger in samples with greater variability in parents' education.

An additional limitation is that we did not include a measure of the adolescent's performance prior to seventh grade. Doubtless some variables in our model, such as mother's perception of the adolescent's math ability, are influenced by prior performance.

The study is also limited insofar as only mothers, and not fathers, were studied. An important next step in research will be to examine these same issues with a sample of fathers and adolescents.

CONCLUSION

This research sought to examine mothers' communications with their adolescent in high school, measuring number of conversations and mothers' elaboration and personal connections in response to a hypothetical statement from the adolescent questioning the usefulness of STEM courses. Overall, we found that mothers varied considerably in their amount of elaboration and personal connections, and elaboration was predicted by mother's education. Personal connections positively predicted adolescents' interest and UV a year later, and, indirectly, actual course-taking 3 years later. Elaboration was also a significant predictor, but its effects were qualified by interactions with the number of conversations. In particular, adolescents took the most STEM courses in high school when mothers engaged in either many conversations about STEM that were less elaborated, or fewer conversations from mothers who elaborated more. These results show the importance of socialization and guidance from parents in encouraging students to take MS courses in high school, yet also point to the complexity of delivering these communications in the most effective manner.

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