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Patterns of Math and English Self-Concepts as Motivation for College Major Selection

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Patterns of Math and English Self-Concepts as Motivation for College Major Selection

What influences students' decisions about whether to pursue a math intensive college major or a field of study requiring more language arts skills? Why do men and women have unequal representation in math intensive majors like engineering and technology? Researchers have offered many explanations to these questions that often focus on differences in academic abilities, academic self-concepts, and academic values. A large body of literature has found that math competence, by itself, is not the primary factor explaining college major choice and cannot explain gender disparities (Ceci, Williams, & Barnett, 2009; Lindberg, Hyde, Petersen, & Linn, 2010). Therefore, any sufficient explanation must include considerations beyond academic achievement. Researchers interested in academic motivation have identified ability beliefs and subjective task values as primary predictors of academic choices, above and beyond math competence and performance (Wigfield & Eccles, 2000; Guo, Marsh, Morin, Parker, & Kaur, 2015; Marsh & Yeung, 1997; Simpkins, Davis-Kean, & Eccles, 2006).

Expectancy-value theory (EVT) posits that individuals' ability beliefs and subjective task values related to various academic tasks predict academic choices, performance, and engagement across these tasks (Eccles et al., 1983; Eccles, 2009). Complementing EVT research, the internal-external frame of reference (I/E) model of academic self-concept and its newer extension, dimensional comparison theory (DCT), states that students compare their achievement between domains when making conclusions about their relative abilities (Marsh, 1986; Marsh, 1990; Möller & Marsh, 2013; Marsh et al., 2014). Therefore, higher math achievement can lead to lower verbal self-concept, and higher verbal achievement can lead to lower math self-concept (Skaalvik & Skaalvik, 2002). Although this theory is well established, the effect of cross domain influences on future academic choices has not been studied extensively.

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Most studies that have investigated the role of self-concept of ability (SCA) on academic choices have focused only on a single domain such as math or English (e.g., Archambault, Eccles, & Vida, 2010; Musu-Gillette, Wigfield, Harring, & Eccles, 2015). However, evidence from both expectancy-value theory and dimensional comparison theory suggests that cross subject area domain comparisons might influence the development of academic ability self-concepts in specific subject areas and thus also influence academic choices such as college major and occupation. When choosing which occupation to prepare for or which college major to take, one's relative SCA and subjective task values may be more important than the absolute values for the various options by themselves. Although at a between person level, the person with the highest math SCA may be more likely to major in math-intensive field than a person with a lower math SCA, at the individual level, it is likely to be relative SCA across different subject areas (e.g., math versus language) that most influences major choice.

To date, only a handful of studies have simultaneously considered multiple subject areas, and the results support the hypothesis that cross subject area comparisons help explain both individual and group differences in academic choices and gender differences (e.g., Wang, Eccles, & Kenny, 2013). However, most of these studies are not longitudinal, and the development of SCA over time across domains and its association with college major selection have not been studied to date. The present study builds on the existing literature by longitudinally investigating the development of academic ability beliefs of math and English in synchrony with each other throughout adolescence, and the extent to which these ability beliefs at various points of adolescence predict later college major selection. Additionally, we investigate gender differences in the development of academic ability self-concepts and choices of college major. By studying underlying patterns of math and English self-concepts of ability and their relation to choice of

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college major, we combine expectancy-value theory and dimensional comparison theory to better understand how individual students may or may not come to identify as "math" people (meaning they identify as more of a math oriented person than an English oriented person).

Theoretical Framework

According to expectancy-value theory, achievement-related choices are directly influenced psychologically by relative expectations of succeeding in a task and the relative subjective task value associated with the task, compared to other options. Expectations for success reflect the perceived competence that an individual has in his or her ability to succeed in a domain in the near and distant future. Because expectancy for success and self-concept of ability within specific subject areas load highly on the same factor, we refer to these two highly related constructs with the term self-concept of ability when referring to perceived competence and personal efficacy. Self-concepts of ability are domain specific rather than global in nature (Wigfield et al., 1997; Marsh et al., 2015). For example, students may perceive themselves as competent in math, but not in English. Students assess their own skills by comparing their performances with those of other people and with their own performances across domains (Eccles, 2009). Furthermore, self-concepts are hierarchical in nature. For example, although a student may get high grades in multiple subjects, he or she may still feel more competent in one subject over another (e.g., math over English). Academic choices are made from a variety of options, and understanding the hierarchy of ability self-concepts is essential in understanding why a student would make one academic choice over another (Eccles, 2011).

Another theory focused on the development of self-concept of ability is the dimensional comparison theory, an extension of the internal-external frame of reference theory of self-concept (Möller & Marsh, 2013). According to the I/E model, self-concept of ability in a

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particular domain is informed in relation to internal and external frames of reference. The external frame of reference primarily reflects various types of social comparisons, such as when a student compares his or her perceived ability in a subject relative to the perceived ability of peers in the same subject. The internal frame of reference refers to how a student internally contrasts performance in one subject against his performance in another school subject. These internal, dimensional comparisons can result in a decreased SCA in one domain because of high achievement in another domain. For example, a student with high math achievement and low English achievement will likely develop a much higher math self-concept of ability than a student with high math achievement and even higher English achievement (Möller & Marsh, 2013). Generally, the better students perceive themselves at math, the less competent they perceive themselves at another subject like English, relative to their math SCA. DCT further adds that the farther apart two subjects are in content the larger the contrast effect will be. For example, math and English cross domain comparisons will likely be significantly more negative (contrasting) than nearer domains like math and physics, which will be less negative or possibly even positive (assimilation).

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SCA, College Major, and Gender Differences

Many longitudinal studies have investigated SCA and subjective task value components in predicting academic choices such as math course taking behavior (Musu-Gillette et al., 2015; Simpkins et al., 2006). However, most studies that have investigated the role of SCA on academic choices have focused on analyzing a single domain, usually mathematics. Consistently, math self-concept of ability predicts high school math course taking behavior (Meece, Wigfield, & Eccles, 1990; Simpkins et al., 2006; Updegraff, Eccles, Barber, & O’Brien, 1996).

Decisions about college major based on self-concepts of ability and task values likely begin to form years before entry into college, possibly as early as 6th grade (Eccles, Vida, & Barber, 2004). A few studies have investigated the extent to which high school ability self-concepts predict college major. In a recent study investigating growth trajectories of math self-concept of ability from fourth grade to college, students who maintained a high SCA in math had a 75% probability of being in a math intensive major (Musu-Gillette et al., 2015). This study did not consider the possible influence of other domains of self-concept such as English on college major.

A few recent studies have considered the dual roles of math and English ability and self-concepts of ability in determining academic choices. In an international study of American and German high school students, cross domain self-concepts in high school and gender were predictive of high school course selection, with the German sample having larger SCA and stereotypical gender differences (Nagy, Garrett, Trautwein, Cortina, Baumert, & Eccles, 2008). German students who were high in English self-concept were less likely to take advanced math courses and German students high in math self-concept were less likely to take advanced English courses. In another study looking at math and English ability and self-concepts in 12th grade and their associations with college major choice, students with high math and moderate verbal abilities were more likely to select a STEM career than students in the high math and high verbal ability group (Wang, Eccles, & Kenny, 2013). Women were more likely to be in the high math/high verbal group, possibly indicating that women had more choices based on their ability beliefs across multiple subjects. The authors suggested that frame of reference effects should be further investigated in subsequent studies. Lauermann, Chow, and Eccles (2015) also investigated the cross-domain effects of self-concepts and values in math and English, and found

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the combination of high perceived ability in both math and English led to a lower probability of math and science careers compared to students with high SCA in math and lower SCA in English. Although these studies looked at math and English self-concepts together, the analyses were cross-sectional and thus could not consider change over time in math and English self-concepts.

The Present Study

Researchers have recently expressed the need for more longitudinal analyses on self-concepts of ability across domains and concerns that analyses that only consider one domain such as math may be inadequate for understanding college major and occupation choices (Lauermann et al., 2015). This seems to be especially true when gender is considered, as prior research has found females to be consistently higher in English SCA than males (Jacobs, Lanza, Osgood, Eccles, & Wigfield, 2002), which may result in more females selecting majors requiring high verbal skills. Unfortunately, despite a significant amount of research stating the importance of understanding the interplay of domain specific self-concepts when studying academic choice, the literature on the subject has been sparse and limited by cross-sectional designs.

In the present study, we seek to expand upon and address these concerns by using a longitudinal study of math and English self-concept of ability from sixth to twelfth grade and then into college, using both a variable-centered and person/pattern-centered approach. Using these two different methods allows general associations to be made and individual differences to be highlighted. A person-centered approach provides a sophisticated method of investigating different clusters of math and English SCA, allowing for structural patterns of self-concepts across subject areas to be revealed at multiple time points across adolescence. Furthermore, we examine the extent to which cluster membership is associated with college major selection.

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Finally, we investigate gender differences in these clusters across adolescence and in college major choice. This study allows us to determine the extent to which college major choice reflects both prior performance and SCA in the most directly related domain specific self-concept, in addition to the intraindividual hierarchy of self-concepts across different subject areas.

The three broad research questions we seek to answer are the following:

1) To what extent are math and English SCA generally associated with one another at different stages of adolescence, as well as with college major? Are there gender differences in math and English SCA throughout adolescence and in choice of college major?
2) What patterns of math and English self-concept beliefs co-occur within individual students at different stages of adolescence? Does cluster membership differ by gender at different stages of adolescence?
3) To what extent does self-concept cluster membership and gender relate to students' choices of a math-related college major, independent of math ability? To what extent does this relationship vary at different stages of adolescence for males and females?

We hypothesize that math and English SCA will be negatively correlated with each other at each wave (Marsh et al., 2014). Math SCA is expected to be positively associated with the level of math in college major, whereas English SCA is expected to be negatively associated with it. Females are expected to have higher English SCA than males throughout adolescence, whereas math SCA is anticipated to be higher for males throughout adolescence. Overall, females are expected to pursue less math intensive majors than males (Lauermann, Chow, & Eccles, 2015)

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For our second research question, we expect clusters to emerge with higher math self-concept relative to English, higher English self-concept relative to math, and clusters with equal self-concept in both domains. We anticipate these clusters to be quite stable throughout adolescence. We expect males to be overrepresented in clusters that are higher in math than English, and we expect females to be overrepresented in clusters that are higher in English than math (Wang, Eccles, and Kenny, 2013).

For our third research question, we hypothesize that students in clusters with higher math self-concept relative to English self-concept will pursue more math intensive majors than students who have lower math self-concept relative to English. Furthermore, we hypothesize that between clusters with equivalent math self-concept but differing English self-concept, the clusters with lower English concept will pursue more math intensive majors than clusters with higher English self-concept. For students possessing equal math and English self-concepts, females will pursue less math intensive majors. Finally, because we expect women to generally be in clusters with higher English SCA than math SCA, they will likely pursue less math intensive majors than males.

Method

Participants

The data used in this study come from the first seven waves of the Michigan Study of Adolescent and Adult Life Transitions (MSALT). MSALT is a longitudinal study that began in 1983, when participants were in the 6th grade. The data used in the analysis spans from 6th grade (approximately 11 years old) to three years after high school (approximately 21 years old). The longitudinal sample included a total number of 2451 students in the first wave in the 6th grade, however, this study uses a subsample of 804 students who reported being in college at age 21.

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The subsample participants were predominantly White (91%) and 57% were female. The participants came from sixteen schools in twelve middle-class school districts in Michigan. The data used was obtained from students and school districts. Students initially completed surveys in school classrooms until the age of 18. Age 21 surveys were mailed to the participants. Grades and test scores were collected from school record data. Missing data and attrition are discussed below.

Measures

Self-concept of ability (SCA). SCA was measured for both math and English during the beginning of 6th grade, end of 7th grade, beginning of 10th grade, and the beginning of 12th grade. Three items were used to measure math SCA (Chronbach's α =.79 to .87) that assessed student perceptions about how good they were in math generally, how good they were at math compared to other subjects, and how good they were in math relative to classmates (sample items, "Compared to most of your other school subjects, how good are you at math?", measured on a Likert scale from 1 = *not at all good* to 7 = *very good*). The three items were worded the same at every wave. Two items were used to measure English SCA (Chronbach's α =.76 to .89). The same two items were used in 6th and 7th grade (general English ability and comparison to classmates), whereas 10th and 12th grade used one different item (general English ability and comparison between domains). See Appendix A for a complete list of items and Table 2 for scale reliabilities.

College Major. Students filled in their major in an open-ended item asking, "What is your college major?" College major was coded from 1 to 4 for level of math required based on an adapted version of Goldman and Hewitt's (1976) scale for coding STEM-related majors. The adapted scale categorizes college majors based on the level of math required from (1) little to no

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math, (2) some math, (3) moderate math, and (4) intensive math. The level of math required per major was based on the average number of math courses required by each major. The adapted version was utilized and updated by Musu-Gillette et al. (2015). For college majors not existing in the scale, two coders independently categorized majors based on similarities with other majors. The coders initially agreed on 90% of the majors, and any discrepancies were discussed until 100% agreement was reached. 131 students had declared double majors, in which case the major with the highest level of math was considered in the analysis. Categories of college majors by level of math required are shown in Table 1.

Moderators and Covariates. Gender moderation was dummy coded with males as the reference group. Math achievement was measured using the Michigan Educational Assessment Program (MEAP) scores that were reported by the school district in the 7th and 10th grade. A scale of the two math scores was created. The MEAP is a test of basic math proficiency measured from 1 to 28 (*M*=25.28*, SD*=2.80), and due to its function as a test of basic skills, the distribution is skewed to the left.

Attrition and Missing Data

The data from MSALT includes a complex pattern of complete and missing data. Of the 2451 participants from 6th grade (Wave 1), 1837 participants responded to questionnaires three years after high school (Wave 7). Of those 1837, 804 participants (44% of remaining sample) completed questionnaires indicating full-time enrollment in college with a major. Females were more likely to have remained in the study by Wave 7 than males. The participants who did not complete Wave 7 questionnaires tended to have lower levels of achievement and self-concepts of ability across multiple Waves. Of the 804 students who completed Wave 7 college questionnaires, there was significant missing data on self-concept measures (e.g., 5% in 7th

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grade and 45% in 12th grade). However, t-tests showed that there were no significant differences between those with missing data and complete data in SCA at other waves. Additionally, 62 students had more than 50% missing data on all SCA variables and were dropped from the analysis sample, as the imputation algorithm used required at least 50% available data. Therefore, the final sample for the profile analyses was 742. Ten students reported undecided/undeclared majors in the college survey, resulting in them being dropped from analyses regarding math intensiveness of college major.

Analysis Plan for Research Question 1

Multiple regression analyses were used to investigate the effect of self-concept of ability with the math level of college major. Gender was included as a key moderator variable and math achievement was included to isolate the predictive effect of self-concepts from actual math ability differences in predicting college major. Models were run for each of the four waves, using self-concept at each wave to predict college major. A variable-centered analysis allowed for understanding the general associations of SCA, gender, and math achievement with the outcome variable, yet it did not allow for analyzing possible individual differences in patterns of math and English self-concepts within students.

Analysis Plan for Research Question 2 and 3

To investigate self-concept of ability patterns, cluster analysis was used. Cluster analysis allowed for classifying individuals into homogeneous groups with respect to their patterns of values for dimensional self-concepts by maximizing within-cluster homogeneity and between-cluster heterogeneity (Magnusson & Törestad, 1993; Wormington, Corpus, & Anderson, 2012). Raw scores for self-concept of ability were used at each wave, as standardized estimates may eliminate the detection of developmental differences at different time points (Cairns, 1986). A

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multi-step analysis was carried out using ROPSTAT (Vargha, Torma, & Berman, 2015), a statistical package for pattern/person-centered analyses. The following steps were performed:

1. Preparatory steps of imputing missing data and removing outliers;
2. Hierarchical cluster analysis followed by K-means relocation clustering.
3. Random sample validation procedure to confirm cluster stability and reliability.

Missing data on self-concept variables was imputed using the twin/nearest neighbor method, which relies on the average squared Euclidean distance as a measure of proximity between cases. For cases missing a measure of self-concept of ability, data were imputed using the case of a twin, a student with complete data whose value for the variable of interest was used to impute the missing value of a neighbor. Proximity is determined based on all self-concept variables across the waves where imputation is not required (Bergman, Magnusson, & El-Khouri, 2003). This method of imputation is commonly used for handling missing data for cluster analysis (see Conley, 2012; Peck, Vida, & Eccles, 2008). After imputing the missing cases, we checked for multivariate outliers using the RESIDAN method (Bergman, 1988b), which identifies outliers prior to clustering. Hierarchical clustering methods are sensitive to outliers that may bias the hierarchical structure at any level of merging, and the cutoff point was a squared Euclidean distance greater than 0.7 (Berman et al., 2003). Eight outliers were removed from the analysis sample.

After the preparatory steps were completed, cluster analysis was performed using Ward's method, a hierarchical agglomerative method that initially assigns each case to its own cluster and step-by-step the most similar clusters are joined together, eventually resulting in one cluster with all cases (Clatworthy, Buick, Hankins, Weinman, & Horne, 2005). Ward's method is based on squared Euclidian distances to create a similarity/dissimilarity matrix, aiming to minimize the

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within-cluster sum of squares (Wormington et al., 2012). Additionally, it makes no assumptions about the nature of the data being used. In order to determine the most suitable cluster solution, both a priori theorizing of clusters and statistical considerations based on the percent of variance explained were considered. The error sum of squares (ESS), a measure of cluster heterogeneity, and the explained error sum of squares (EESS) were calculated for all possible cluster solutions.

$$EEES=100*((TotalESS-ESSofthegivenclustersolution)/TotalESS)$$

An EESS value of 100 implies perfect cluster homogeneity, whereas 0 implies the complete absence of cluster homogeneity (Bergman et al., 2003). ESS values were plotted against EESS values to display an array of possible cluster solutions based on how much additional error was included by reducing a cluster from the previous solution. This analysis was carried out at every wave independently, as it is possible that a different number of clusters would emerge at different developmental stages.

K-means clustering was performed to fine-tune cluster homogeneity by reassigning cases to the optimal cluster. In K-means clustering, the number of clusters is chosen before relocation using the initial hierarchical method. Centroids (i.e., profiles of means for the variables in the clusters) from the Ward's analysis were used as starting points, and all cases within a certain distance of the centroid became assigned to that cluster until all cases were assigned (Wormington et al., 2012). The K-means analysis reduced the homogeneity coefficient of the clusters at each wave, confirming that case relocation was appropriate. Cluster stability and reliability was tested by drawing a random split of the sample and confirming that similar clusters appeared. After all cluster solutions were completed, cross-tabulations were used to test for gender differences in cluster membership. Analyses of variance and covariance (ANCOVA)

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were used to test differences in level of math required by major depending on clusters, gender, and prior math achievement.

Results

There were several important descriptive findings to highlight. Reliabilities, means, and standard deviations are reported in Table 2. First, at the mean level for the sample, both math and English SCA decreased over time from 6th grade to 12th grade. Correlations between SCA and analysis variables for all waves are displayed in Table 3. Although math SCA was positively correlated with English SCA in 6th grade (r=.29, p<.001) and 7th grade (r=.12, p<.001), there was a downward trend for the magnitude to diminish until math SCA was negatively correlated with English SCA by 12th grade (r=-.26, p<.001). Additionally, English SCA in 12th grade was negatively correlated with the level of math required by college major (r=-.19, p<.001).

Many gender differences also emerged. Some of these findings have been previously reported for 6th and 7th grade (Wigfield, Eccles, Mac Iver, Reuman, & Midgley, 1991) and high school (Nagy et al., 2008). Females had significantly lower mean math SCA than boys at every wave, although the 12th grade difference was only marginally significant (t=1.95, p=0.051). However, math achievement between genders did not differ. For English SCA, females had significantly higher SCA than males in grades 7, 10, and 12. There was a highly significant mean difference in the math intensiveness of college majors between genders (t=5.42, p<.001), where males had a mean level of math required of 2.82 (i.e., close to moderate math) compared to 2.41 for girls. Being female was negatively correlated with the level of math required by major (r=-.20, p<.001).

The results of the multiple regression analyses are presented in Table 4. Math SCA was positively associated with level of math by college major at every wave, although English SCA

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was not significantly associated with level of math until 7th grade. By 12th grade, a one standard deviation increase in English SCA was associated with a 0.12-unit decrease in math intensive college major ($p<.01$). Being female was associated with .35 to .38-unit decrease in math intensive majors at all waves ($p<.001$). Lastly, math achievement was not significantly associated with the outcome measure in 6th or 12th grade, but had a small and significant association of .10 in 7th grade and .09 in 10th grade ($p<.05$). We suspect this association was small in magnitude and inconsistent over time due to our measure of math achievement being a test of competence exhibiting a ceiling effect. Interactions between math and English SCA were not significant, nor were interactions between gender and self-concepts. Ordered logistic regression analyses were run as a robustness check, and the results confirmed the previous findings. Although these results inform general trends of SCA and gender differences, cluster analyses reveal a more nuanced understanding.

Cluster Analysis

To answer research question two, cluster analyses were conducted**.** After twin imputation, eight multivariate outliers were identified and removed. The initial results from Ward's hierarchical method revealed that a cluster solution between five and ten clusters could be considered by analyzing the ESS and EESS plots. After investigating the specific patterns in each cluster solution, we determined that a six-cluster solution best fit and explained the data in 6th grade. The five-cluster solution did not create enough meaningfully distinct clusters, and the seven-cluster solution began to break one distinct cluster into subgroups that was not theoretically meaningful. K-means clustering was used to relocate cases, correcting preliminary classification and increasing cluster homogeneity. The final six-cluster solution in 6th grade accounted for 77% of the variance, above prior used thresholds of 50% or 67% (Hayenga &

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Corpus, 2010; Wormington et al., 2012). The same process was carried out at each subsequent wave, with seven-cluster solutions emerging during 7th, 10th, and 12th grade. However, the specific configuration of clusters differed from wave to wave. Complete EESS and ESS plots are available in the supplemental file.

We describe the clusters in terms of the extent to which the math and English SCA were high, medium, or low relative to other clusters at that wave. We understand that this operational definition of high, medium and low is unique to each wave. It would be more accurate to label these as high for wave, medium for wave and low for wave but this labeling is very cumbersome. We note this so the reader is aware of the operational meaning of the terms high, medium, and low in this paper. Cluster means and homogeneity coefficients are displayed in Table 5 and Figure 1 illustrates clusters visually. In the 6th grade, self-concept clusters were labeled as low math-low English (n=136; 18.6%), low math-medium English (n=52; 7.1%), medium math-low English (n=152; 20.8%), medium math-high English (n=175; 23.9%), high math-medium English (n=125; 17.1%), and high math-high English (n=92; 12.6%). In 7th grade, the seven-cluster solution included the clusters low math-high English (n=166; 22.7%) and high math-low English (n=78; 10.7%), although the medium math-high English cluster did not appear. In 10th and 12th grade, the seven-cluster solutions included the largest cluster medium math-medium English (n=151; 20.6% in 10th, n=178; 24.3% in 12th, respectively), although the 12th grade solution did not include the high math-high English cluster. Of all the high math-high English students in 10th grade (n=157), 31.2% fell into the high math-medium English cluster and 31.2% were in the medium math-high English clusters in 12th. Overall, the cluster solutions remained quite stable over time, as most clusters appeared at each wave. However, the mean SCA for both math and English for the same cluster over time generally decreased. For example, whereas the

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high math-high English cluster in 6th grade had a cluster centroid of 6.39 for math and 6.72 for English, the same cluster in 10th grade had a cluster centroid of 5.95 for math and 6.24 for English.

Cluster Stability and Movement

To investigate cluster stability and movement at the person level we used a contingency table of 6th and 12th grade clusters. The cross-tabulation analysis shows the number and percentage of individuals whose exhibit cluster stability or movement. Overall, 12.5% of students remained stable in clusters. The most stable clusters were those in which students felt highly competent in one domain but not the other (i.e., the medium math-high English and high math-medium English clusters). Approximately 24% of students in these moderately-differentiated clusters remained stable from 6th to 12th grade, whereas 22% showed even further separation between domains by moving to a highly-differentiated cluster (i.e., low math-high English or high math-low English). Another cluster of interest was the high math-high English cluster in 6th grade, because this cluster did not emerge in 12th grade. Of the 92 students in this cluster, 21% still felt equally capable in both domains but moved to the medium math-medium English cluster, 42% moved to the medium math-high English cluster, and 15% moved to the high math-medium English cluster.

Gender Differences in Cluster Membership

To investigate gender differences in cluster membership we used adjusted standardized residuals (ASR) from cross tabulations at each time point. The results of the chi-squared analyses are presented in Appendix B. Adjusted residuals provide a standardized measure of the strength of the difference in observed and expected values, indicating whether the observed frequency is greater than or less than expected by chance. Significant gender differences emerged after the

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sixth grade, and the findings were generally in line with our hypotheses. In 7th grade, females were overrepresented in the medium math-high English cluster (ASR=2.87, $p<0.01$), whereas males were overrepresented in the high math-low English cluster (ASR=3.68, $p<.001$). In 10th grade, males were overrepresented in the low math-low English cluster (ASR=2.46, $p<.05$), whereas females were overrepresented in the low math-high English cluster (ASR=2.75, $p<.01$). In 12th grade, females were overrepresented in the medium math-high English cluster (ASR=2.17, $p<.05$), whereas males were overrepresented in the high math-low English cluster (ASR=2.49, $p<0.05$).

Associations between Cluster Membership and College Major

Cross tabulation and ASR analyses were conducted to determine if cluster membership was related to the math-intensiveness of chosen college majors. The results of the chi-squared analyses are available in the supplemental file. The same analyses were then done separately by gender to test whether cluster membership was differentially related to the math-intensiveness of college major for males and females. Math intensive majors (e.g., engineering and physics) refer to majors that require the highest amount of math and are classified as 4 in Table 1. In 6th grade, students in the low math-low English cluster were underrepresented in math intensive majors (ASR=-2.59, $p<.01$), as were students in the low math-medium English cluster (ASR=-.2.65, $p<.01$). Additionally, students in the high math-medium English cluster were overrepresented in math intensive majors (ASR=4.13, $p<.001$), but the students in the high math-high English cluster were neither over-nor underrepresented. This statistically significant finding did not differ by gender. In 7th grade, both the students in the high math-low English cluster (ASR=2.44, $p<.05$) and the high math-medium English cluster (ASR=3.36, $p<.01$) were overrepresented in math intensive majors, but the students in the high math-high English cluster were neither over-

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nor underrepresented. In the 10th grade, both the students in the low math-medium English (ASR=-2.08, $p<0.05$) and low math-high English clusters (ASR=-2.32, $p<0.05$) were underrepresented in intensive math majors, whereas the high math-low English cluster was overrepresented in intensive math majors (ASR=4.79, $p<.001$). In 12th grade, the same pattern emerged, with the low math-medium English (ASR=-3.08, $p<0.01$) and low math-high English clusters (ASR=-4.09, $p<.001$) were underrepresented in intensive math majors, whereas the high math-low English cluster (ASR=4.55, $p<.001$) and high math-medium English (ASR=5.35, $p<.001$) clusters were overrepresented in intensive math majors. ASR analyses did not reveal any gender differences in representation in math-intensive majors.

One-way ANOVAs were conducted to test whether self-concept of ability clusters differed significantly in the math-intensiveness of college majors. As early as 6th grade, there was already a significant difference between self-concept clusters and the level of math required by college major, $F(5, 716)=4.92$, $p<.001$. To test the robustness of this result, prior achievement was controlled for. A one-way ANCOVA revealed that there was a significant difference between cluster membership on college major, controlling for prior math achievement, $F(6,709)=4.90$, $p<.001$. Next, a two-way ANOVA was run to examine the effect of gender and self-concept cluster membership on level of math required by college major. The overall model was statistically significant, $F(12, 703)=5.02$, $p<.001$. Both gender and cluster membership were significant ($F=18.67$, $p<.001$ and $F=3.47$, $p<.01$, respectively), but the interaction between gender and cluster membership was not significant ($F=.62$, $p=.69$), implying that the effect of gender on college major was not specific to particular patterns of self-concepts, even though the clusters differed in the ratio of males to females.

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The same set of analyses were performed at all subsequent waves, and the results were significant for all tests, with the exception that prior math ability was not a significant predictor in the 12th grade data analyses (F=3.22, p=.07). Post hoc analyses using Bonferroni adjusted pairwise comparisons were conducted at every wave to test for mean differences in the math-intensiveness of college majors, controlling for prior achievement. Specific pairwise comparisons were chosen to test our hypothesis that between clusters with equivalent math SCA but differing English SCA, the clusters with lower English SCA will pursue more math-intensive majors than clusters with higher English SCA. In the 6th grade, none of the three tests (low math-low English vs low math-medium English, medium math-low English vs medium math-high English, and high math-high English vs high math-medium English) were significant. In the 7th grade, although all pairwise tests of equally low math SCA and tests of equally medium math SCA were not significant, the high math-medium English cluster (M=2.82, SD=1.08) had a significantly higher mean level of math intensive majors than the high math-high English cluster (M=2.48, SD=1.03). In 10th grade, the low math-high English cluster (M=2.19, SD=0.96) had a significantly lower mean level of math-intensive college majors than the low math-low English cluster (M=2.68, SD=1.00), and the high math-high English cluster (M=2.66, SD=1.05 had a significantly lower mean level of math-intensive college majors than the high math-low English cluster (M=3.05, SD=0.99). None of the five tests in 12th grade were significant.

Discussion

The present study drew from expectancy value theory and dimensional comparison theory to examine the development of adolescent math and English self-concepts, their associations with college major, and gender differences. We have added to the literature by including a longitudinal person-centered approach that sheds new light on individual differences

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in self-concept patterns and how intraindividual hierarchies of self-concepts develop and predict choice of college major.

Variable-Centered Approaches

As expected and predicted, males generally had higher math self-concept than females, and females had higher English self-concept than males. The longitudinal correlations between math and English SCA were particularly noteworthy. In middle school, the two were positively correlated, but by 12th grade they were negatively correlated. Prior research on 15-year old adolescents had found small or near-zero correlations between math and English SCA (Marsh & Hau, 2004). However, our finding may be explained by DCT, which shows that their self-concept of ability in one domain becomes negatively associated with their self-concept in a distal, unrelated domain. DCT further hypothesizes that math and English are the two most distal domains (Marsh, et al., 2015). This developmental pattern suggests that students may perceive themselves as competent in multiple domains early in adolescence, but over time, as hierarchies of SCA develop, they gravitate towards seeing themselves as more of a ‘math’ or ‘verbal’ person. Our regression models supported this finding, showing that over time, the association between English SCA and math intensive college is increasingly negative. This finding may also align with identity theorists who have proposed the importance of adolescence as a pivotal period for identity achievement, suggesting self-concept clarity is an important part of identity commitment, where the self is clearly defined and internally consistent (Van Dijk, Branje, Keijsers, Hawk, Hale III, & Meeus, W, 2014). It may be that self-concept clarity and consistency occur as one prepares to make important academic choices like college major. The gender patterns of self-concepts would also be consistent with theories on gender intensification (Roberts, Sarigiani, Petersen, & Newman, 1990), where social pressure and norms to think and

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behave according to sex stereotypes increases in adolescence and the relation between school achievement and a positive self-image should increase among boys and decrease among girls.

Although Nagy et al.'s (2008) analysis using the same dataset failed to show negative cross domain self-concept effects on high school course taking for American students, it is especially interesting that the effect appeared in the present study when investigating its association with math intensive college majors. There could be many reasons for this discrepancy. First, it could be that advanced math and English courses are the typical program for students who have college aspirations, regardless of specific interest or career aspirations (Lauermann et al., 2015). Second, it may be that choice of college major is a more independent choice than high school coursework, and therefore the effect is not fully seen until college. Third, the utility in taking advanced high school courses for college acceptance may be motivating enough to encourage students to take advanced math and English courses, despite a lack of long term interest in one of them. However, as college major is often the final academic choice that cascades into more narrow career choices, it may be that students opt for a major where they most expect to succeed long term. Although dimensional comparison theory has shown these cross domain self-concepts to negatively predict one another, longitudinally extending its effects to college major choice is a finding directly related to expectancy-value theory, highlighting the complimentary nature of these two theories.

Person-Centered Cluster Approaches

The cluster analyses revealed a six to seven-cluster solution of various patterns of self-concepts between 6th and 12th grade. Although most patterns of clusters reappeared at each wave, the high math-high English cluster was not evident in 12th grade, with the majority of students previously in that cluster moving either into the high math-medium English or the high

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English-medium math clusters. This may reflect the need for high achievers to develop a more differentiated academic identity as they move towards college and the need to select majors and future careers. Although individuals with high math achievement may also be competent in the verbal domain, some students may come think of themselves as more of ‘math’ person than a ‘verbal’ person or a 'smart' person. (Marsh & Hau, 2004). DCT theorists suggest this differentiation is a likely consequence of internal comparisons in the ability self-concept formation process (e.g., Marsh & Hau, 2004). However, little scholarship has focused on the exact cues individuals use in making this type of differentiation when their level of objective performance is quite similar. Equally important, scholars have theorized the social and cultural forces that might influence this developmental process. Social contextual characteristics might moderate the rate, direction, and the extent to which differentiated ability self-concepts develop (Markus & Kitayama, 1991). If individuals are forced to specialize in their academic subjects at a younger age, it is possible that the high-high groups will begin the differentiation process at a younger age.

Stereotypical gender differences also emerged in cluster membership starting in seventh grade. Every gender difference followed the same pattern; females were overrepresented in those clusters with higher English SCA relative to math, whereas males were overrepresented in those clusters with higher math SCA relative to English. Why does this pattern consistently emerge despite no differences in actual math performance? Perhaps this difference can be explained by varying causal attributions patterns of success, where males and their parents often attribute their success to talent, whereas females and their parents often attribute their success to effort, which over time may lead to gender differences in math self-concept (Räty, Vänskä, Kasanen, & Kärkkäinen, 2002; Sáinz & Eccles, 2012; Eccles & Wigfield, 2002; Yee & Eccles, 1988).

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Alternatively, it may be that males brag about their math competence more than women, leading to females making upward social comparisons about their ability relative to male classmates (Guimond & Roussel, 2001; Yee & Eccles, 1988). Another possibility is perhaps females work harder than males in their math courses and are thus are more likely to attribute their math successes to effort (Yee & Eccles, 1988). We believe these possible explanations need to be replicated with more current data.

Results of the cluster analysis also revealed the predicted associations with college major choice. Students in the high math-medium English cluster in 6th grade were more likely than expected by chance to end up in math intensive majors, but students in the high math-high English cluster were not, despite having similar confidence in their math ability. This interaction did not show up in the variable centered analyses. The same relationship was also found in 7th grade, with the newly emerged high math-low English cluster also more likely than expected by chance to end up in intensive math majors. This pattern suggests that some students are already reaching the point of identifying as a ‘math’ person by the end of elementary school or middle school and committing themselves to pursuing math intensive careers, whereas those who felt competent in both domains were still developing their academic identities. The same pattern is evident in high school, where clusters high in math and lower in English were overrepresented in math intensive majors, whereas clusters with low math-high English were overrepresented in majors with little to no math. This seems to indicate that by 10th grade, ability belief disparities between domains lead students to identifying with one domain over the other.

Finally, both variable-centered and person-centered results showed that females generally went into less math intensive majors than males, regardless of cluster membership. Beyond considering gender disparities in math SCA, an ipsative approach to intraindividual self-concept

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hierarchies reveal a more nuanced story of ability self-concepts. However, while the current pattern analysis advances theoretical perspectives on the role of self-concepts in college major choice, what might explain why these self-concept patterns emerge in the first place, such that females end up overrepresented in high English clusters and end up pursuing math intensive majors less than males? One reason may be gender-role stereotyped socialization, where females place higher value than males on the importance of making occupational sacrifices for one's family and on having a job that helps others, whereas males place more value on earning a higher income, seeking out more challenging tasks, and doing work that involves the use of math and computers (Eccles, 2011). Additionally, the role of subjective task values such as interest value, utility value, and attainment value may also explain gender differences in college major selection, as women have reported lower task values in numerous studies (Eccles, 1994; Zarrett, Malanchuk, Davis-Kean, & Eccles, 2006), and EVT research has found that subjective task values are predictive of academic choices (Durik, Vida, & Eccles, 2006; Guo, Parker, Marsh, & Morin, 2015). Another reason may be the perception of math intensive careers such as computer science, engineering, and physics as nerdy, stereotypes that may be incompatible with women's view of themselves as feminine or may be less acceptable for females than for males (Cheryan, Plaut, Handron, & Hudson, 2013; Margolis & Fisher, 2003).

Limitations and Future Directions

The current study is the first to employ longitudinal cluster analyses of math and English SCA to relate to the choice of college major. The results provide an important contribution to EVT and DCT. However, there are a few limitations that must be considered when interpreting the results. As the study relied on longitudinal correlational data, any causal interpretations are tentative as the relationships between variables are likely bidirectional. Additionally, the sample

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had limited ethnic or racial diversity, which may limit generalizations to other populations. However, the underlying psychological process of dimensional comparisons in determining self-concept hierarchies does not appear to be unique to a particular racial group. Another possible point of concern is the age of the data. The sixth-grade data were collected in 1984-1985 and the college major data from 1992-1993, and one may question if the findings would replicate today, where there appears to be greater societal emphasis on gender equality in educational attainment. However, recent literature has shown that women, relative to men, are still shunning many math-intensive majors such as physics, computer science, and engineering. Gender stereotypes, lower sense of belonging, and lower self-efficacy amongst women remain prevalent in these fields and may explain these disparities in college major selection (Cheryan, Ziegler, Montoya, & Jiang, 2017). Therefore, although we encourage more longitudinal studies to investigate the development of adolescent ability beliefs and college major choice, we believe that our findings are still relevant.

Overall, these findings have implications for interventions aimed at raising self-concepts, in addition to the theoretical development of SCA. To date, interventions on self-concept have focused on single domains such as physics (e.g., Häussler & Hoffmann, 2002) or math (e.g., O'Mara, Marsh, Craven, & Debus, 2006). If the desire is to increase self-concept in a particular domain, in order to motivate students towards particular careers, then intervention research must realize that the interplay of multiple self-concepts within a person must be considered. Further research should investigate if attempts to increase SCA in one domain leads to a pernicious side effect of decreasing SCA in another domain. This has ethical implications for student autonomy in determining their own educational and career aspirations. Additionally, future research should investigate a larger constellation of self-concepts together, including math, English, and science.

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Many science majors are math intensive, so understanding how biology, chemistry, and physics self-concepts operate in concert with math SCA would be valuable. As this study was the first to consider a person-centered approach to SCA, replication studies that investigate other populations with different schooling environments would contribute to the robustness of the findings. Additionally, although the current study only focused on math-intensive majors, investigating the choice of college majors requiring strong English language skills would be valuable. For students who see themselves as ‘English people, strong verbal skills are relevant to a wide range of majors that may not be as easily classified as high-math fields.

Another important topic for future research would be an investigation into the sources of input for self-concept at different developmental stages. Understanding the unique contributions of parents, teachers, and peers on self-concept at various points in childhood and adolescence may open the door to creating developmentally appropriate interventions. Finally, to better understand gender disparities in the enrollment of math intensive college majors and occupations, cost components from EVT should be studied as possible explanations (Flake, Barron, Hulleman, McCoach, & Welsh, 2015; Gaspard, Häfner, Parrisius, Trautwein, Nagengast, 2017). Women may perceive particular majors and careers as more emotionally costly (e.g., anxiety inducing) or costly in terms of giving up valued alternatives, resulting in lower enrollment and commitment to those fields.

Conclusion

This is one of the first studies focused on the ontogeny of patterns of math and English self-concepts of ability throughout adolescence. The findings stress the importance of the intraindividual hierarchy of self-concepts within a student when attempting to predict and

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understand academic choices like college major. An ipsative perspective may be key to understanding why a student selects one particular option instead of another.

Although a variable-centered approach provided general insights into the associations of math and English SCA across the sample on the math-relatedness of college majors, means, correlations, and regression coefficients were anchored in the aggregate and therefore could not differentiate group-level from person-level stability or associations (Lamiell, 1981; see Parker, Marsh, Morin, Seaton, & Van Zenden, 2015). Additionally, the predicted interaction did not emerge in variable centered analyses but did emerge in the patterned centered analyses. Thus, these techniques could not properly address the question of the hierarchy of intraindividual self-concepts with respect to stability, change over time, or predicting distal outcomes (Young & Mroczek, 2003). A person-centered approach using cluster analysis was thus an appropriate and sophisticated statistical approach to studying self-concept patterns and their associations with distal outcomes. Further research should consider such statistical methods, including latent class growth analysis (LCGA) and growth mixture modeling (GMM). These person-centered approaches will allow for the emergence of unique subgroups that are meaningful in the study of persons and their individual differences.

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References

Archambault, I., Eccles, J. S., & Vida, M. N. (2010). Ability self-concepts and subjective value in literacy: Joint trajectories from grades 1 through 12. *Journal of Educational Psychology*, *102*(4), 804. doi: 10.1037/a0021075

Bergman, L. R., Magnusson, D., & El Khouri, B. M. (2003). *Studying individual development in an interindividual context: A person-oriented approach*. Psychology Press.

Cairns, R. B. (1986). Phenomena lost. In J Valsiner (Ed), *The individual subject and scientific psychology* (pp. 97-111). Boston, MA: Springer.

Ceci, S. J., Williams, W. M., & Barnett, S. M. (2009). Women's underrepresentation in science: Sociocultural and biological considerations. *Psychological Bulletin, 135*(2), 218-261. doi:http://dx.doi.org/10.1037/a0014412

Cheryan, S., Plaut, V. C., Handron, C., & Hudson, L. (2013). The stereotypical computer scientist: Gendered media representations as a barrier to inclusion for women. *Sex Roles, 69*(1-2), 58-71. doi:http://dx.doi.org/10.1007/s11199-013-0296-x

Cheryan, S., Ziegler, S. A., Montoya, A. K., & Jiang, L. (2017). Why are some STEM fields more gender balanced than others? *Psychological Bulletin, 143*(1), 1-35. doi:http://dx.doi.org/10.1037/bul0000052

Clatworthy, J., Buick, D., Hankins, M., Weinman, J., & Horne, R. (2005). The use and reporting of cluster analysis in health psychology: A review. *British journal of health psychology*, *10*(3), 329-358.

Conley, A. M. (2012). Patterns of motivation beliefs: Combining achievement goal and expectancy-value perspectives. *Journal of Educational Psychology*, *104*(1), 32. doi:10.1037/a0026042

DRAFT

Durik, A. M., Vida, M., & Eccles, J. S. (2006). Task values and ability beliefs as predictors of high school literacy choices: A developmental analysis. *Journal of Educational Psychology, 98*(2), 382-393. doi:http://dx.doi.org/10.1037/0022-0663.98.2.382

Eccles, J. S. (1994). Understanding women's educational and occupational choices. *Psychology of Women Quarterly*, *18*, 585–609. doi:10.1111/j.1471-6402.1994.tb01049.x

Eccles, J. (2009). Who am I and what am I going to do with my life? Personal and collective identities as motivators of action. *Educational Psychologist*, *44*(2), 78-89. doi: 10.1080/00461520902832368

Eccles, J. (2011). Gendered educational and occupational choices: Applying the Eccles et al. model of achievement-related choices. *International Journal of Behavioral Development*, *35*(3), 195-201. doi: 10.1177/0165025411398185

Eccles (Parsons), J., Adler, T. F., Futterman, R., Goff, S. B., Kaczala, C. M., Meece, J. L., et al. (1983). Expectations, values and academic behaviors. In J. T. Spence (Ed.), *Perspective on Achievement and Achievement Motivation* (pp. 75–146). San Francisco: W. H. Freeman.

Eccles, J. S., Vida, M. N., & Barber, B. (2004). The relation of early adolescents’ college plans and both academic ability and task-value beliefs to subsequent college enrollment. *The Journal of Early Adolescence*, *24*(1), 63-77.

Eccles, J. S., & Wang, M. T. (2015). What motivates females and males to pursue careers in mathematics and science? *International Journal of Behavioral Development*, *40*(2), 100-106. doi: 10.1177/0165025415616201

DRAFT

DRAFT

Eccles, J. S., & Wigfield, A. (2002). Motivational beliefs, values, and goals. *Annual review of psychology*, *53*(1), 109-132. Retrieved from http://www.annualreviews.org/doi/full/10.1146/annurev.psych.53.100901.135153

Flake, J., Barron, K. E., Hulleman, C. S., McCoach, D. B., & Welsh, M. E. (2015). Understanding cost: The Forgotten component of expectancy-value theory. *Contemporary Educational Psychology, 41,* 232-244. http://dx.doi.org/10.1016/j.cedpsych.2015.03.002

Gaspard, H., Häfner, I., Parrisius, C., Trautwein, U., & Nagegast, B. (2017). Assessing task values in five subjects during secondary school: Measurement structure and mean level differences across grade level, gender, and academic subject. *Contemporary Educational Psychology*, *48*, 67-84. http://dx.doi.org/10.1016/j.cedpsych.2016.09.003

Guimond, S., & Roussel, L. (2001). Bragging about one's school grades: Gender stereotyping and students' perception of their abilities in science, mathematics, and language. *Social Psychology of Education*, *4*(3-4), 275-293. doi: 10.1023/A:1011332704215

Guo, J., Marsh, H. W., Morin, A. J., Parker, P. D., & Kaur, G. (2015). Directionality of the associations of high school expectancy-value, aspirations, and attainment a longitudinal study. *American Educational Research Journal, 52*(2), 371-402. doi: 10.3102/0002831214565786

Guo, J., Parker, P. D., Marsh, H. W., & Morin, A. J. S. (2015). Achievement, motivation, and educational choices: A longitudinal study of expectancy and value using a multiplicative perspective. *Developmental Psychology, 51*(8), 1163-1176. doi:http://dx.doi.org/10.1037/a0039440

Häussler, P., & Hoffmann, L. (2002). An intervention study to enhance girls' interest, self-concept, and achievement in physics classes. *Journal of Research in Science Teaching*, *39*(9), 870-888. doi: 10.1002/tea.10048

Hayenga, A. O., & Corpus, J. H. (2010). Profiles of intrinsic and extrinsic motivations: A person-centered approach to motivation and achievement in middle school. *Motivation and Emotion*, *34*(4), 371-383. doi: 10.1007/s11031-010-9181-x

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. doi: 10.1111/1467-8624.00421

Lamiell, J. T. (1981). Toward an idiothetic psychology of personality. *American Psychologist*, *36*(3), 276. http://dx.doi.org/10.1037/0003-066X.36.3.276

Lauermann, F., Chow, A., & Eccles, J. S. (2015). Differential effects of adolescents' expectancy and value beliefs about math and english on math/science-related and human services-related career plans. *International Journal of Gender, Science and Technology*, *7*(2), 205-228. Retrieved from http://genderandset.open.ac.uk/index.php/genderandset/article/viewpdfinterstitial/393/674

Lindberg, S. M., Hyde, J. S., Petersen, J. L., & Linn, M. C. (2010). New trends in gender and mathematics performance: a meta-analysis. *Psychological Bulletin*, *136*(6), 1123. doi: 10.1037/a0021276

Magnusson, D., & Torestad, B. (1993). A holistic view of personality: A model revisited. *Annual Review of Psychology*, *44*(1), 427-452. doi: 10.1146/annurev.ps.44.020193.002235

Margolis, J., & Fisher, A. (2003). *Unlocking the clubhouse: Women in computing*. MIT press. doi: 10.1145/611892.611896

DRAFT

Markus, H. R., & Kitayama, S. (1991). Culture and the self: Implications for cognition, emotion, and motivation. *Psychological Review, 98*(2), 224-253. doi:http://dx.doi.org/10.1037/0033-295X.98.2.224

Marsh, H. W. (1986). Verbal and math self-concepts: An internal/external frame of reference model. *American Educational Research Journal*, *23*(1), 129-149. Retrieved from http://www.jstor.org/stable/pdf/1163048.pdf

Marsh, H. W. (1990). Influences of internal and external frames of reference on the formation of math and English self-concepts. *Journal of Educational Psychology*, *82*(1), 107. http://dx.doi.org/10.1037/0022-0663.82.1.107

Marsh, H. W., & Hau, K. T. (2004). Explaining paradoxical relations between academic self-concepts and achievements: Cross-cultural generalizability of the internal/external frame of reference predictions across 26 countries. *Journal of Educational Psychology*, *96*(1), 56-67. http://dx.doi.org/10.1037/0022-0663.96.1.56

Marsh, H. W., & Yeung, A. S. (1997). Causal effects of academic self-concept on academic achievement: Structural equation models of longitudinal data. *Journal of Educational Psychology*, *89*(1), 41-54. http://dx.doi.org/10.1037/0022-0663.89.1.41

Marsh, H. W., Kuyper, H., Seaton, M., Parker, P. D., Morin, A. J., Möller, J., & Abduljabbar, A. S. (2014). Dimensional comparison theory: An extension of the internal/external frame of reference effect on academic self-concept formation. *Contemporary Educational Psychology*, *39*(4), 326-341. doi:10.1016/j.cedpsych.2014.08.003

Marsh, H. W., Lüdtke, O., Nagengast, B., Trautwein, U., Abduljabbar, A. S., Abdelfattah, F., & Jansen, M. (2015). Dimensional comparison theory: Paradoxical relations between self-

DRAFT

beliefs and achievements in multiple domains. *Learning and Instruction*, *35*, 16-32. doi: 10.1016/j.learninstruc.2014.08.005

Meece, J. L., Wigfield, A., & Eccles, J. S. (1990). Predictors of math anxiety and its influence on young adolescents' course enrollment intentions and performance in mathematics. *Journal of Educational Psychology*, *82*(1), 60. http://dx.doi.org/10.1037/0022-0663.82.1.60

Möller, J., & Marsh, H. W. (2013). Dimensional comparison theory. *Psychological Review*, *120*(3), 544. http://dx.doi.org/10.1037/a0032459

Musu-Gillette, L. E., Wigfield, A., Harring, J. R., & Eccles, J. S. (2015). Trajectories of change in students' self-concepts of ability and values in math and college major choice. *Educational Research and Evaluation*, *21*(4), 343-370. http://dx.doi.org/10.1080/13803611.2015.1057161

Nagy, G., Garrett, J., Trautwein, U., Cortina, K. S., Baumert, J., & Eccles, J. S. (2008). Gendered high school course selection as a precursor of gendered careers: The mediating role of self-concept and intrinsic value. In H. M. G. Watt & J. S. Eccles (Eds.), *Gender and occupational outcomes: Longitudinal assessments of individual, social, and cultural influences* (pp. 115-143). Washington, DC, US: American Psychological Association. http://dx.doi.org/10.1037/11706-004

Niepel, C., Brunner, M., & Preckel, F. (2014). The longitudinal interplay of students' academic self-concepts and achievements within and across domains: Replicating and extending the reciprocal internal/external frame of reference model. *Journal of Educational Psychology*, *106(4),* 1170. doi: 10.1037/a0036307

DRAFT

O'Mara, A. J., Marsh, H. W., Craven, R. G., & Debus, R. L. (2006). Do self-concept interventions make a difference? A synergistic blend of construct validation and meta-analysis. *Educational Psychologist*, *41*(3), 181-206. doi: 10.1207/s15326985ep4103_4

Parker, P. D., Marsh, H. W., Morin, A. J., Seaton, M., & Van Zanden, B. (2015). If one goes up the other must come down: Examining ipsative relationships between math and English self-concept trajectories across high school. *British Journal of Educational Psychology*, *85*(2), 172-191. doi:10.1111/bjep.12050

Peck, S. C., Vida, M., & Eccles, J. S. (2008). Adolescent pathways to adulthood drinking: sport activity involvement is not necessarily risky or protective. *Addiction*, *103*(s1), 69-83.

Räty, H., Vänskä, J., Kasanen, K., & Kärkkäinen, R. (2002). Parents' explanations of their child's performance in mathematics and reading: A replication and extension of Yee and Eccles. *Sex Roles*, *46*(3), 121-128. doi: 10.1023/A:1016573627828

Roberts, L.R., Sarigiani, P.A., Petersen, A. C. and Newman, J.L. (1990). Gender differences in the relationship between achievement and self-image during early adolescence. *Journal of Early Adolescence, 10*, 159–175. doi: 10.1177/0272431690102004

Sáinz, M., & Eccles, J. (2012). Self-concept of computer and math ability: Gender implications across time and within ICT studies. *Journal of Vocational Behavior*, *80*(2), 486-499. http://dx.doi.org/10.1016/j.jvb.2011.08.005

Simpkins, S. D., & Davis-Kean, P. E. (2005). The intersection between self-concepts and values: Links between beliefs and choices in high school. *New Directions for Child and Adolescent Development*, *2005*(110), 31-47. doi:10.1037/0012-1649.42.1.70

DRAFT

Simpkins, S. D., Davis-Kean, P. E., & Eccles, J. S. (2006). Math and science motivation: A longitudinal examination of the links between choices and beliefs. *Developmental Psychology*, *42*(1), 70. doi: 10.1037/0012-1649.42.1.70

Skaalvik, E. M., & Skaalvik, S. (2002). Internal and external frames of reference for academic self-concept. *Educational Psychologist*, *37*(4), 233-244. http://dx.doi.org/10.1207/S15326985EP3704_3

Updegraff, K. A., Eccles, J. S., Barber, B. L., & O'Brien, K. M. (1996). Course enrollment as self-regulatory behavior: Who takes optional high school math courses? *Learning and Individual Differences*, *8*(3), 239-259. doi:10.1016/S1041-6080(96)90016-3

Van Dijk, M. P., Branje, S., Keijsers, L., Hawk, S. T., Hale III, W. W., & Meeus, W. (2014). Self-concept clarity across adolescence: Longitudinal associations with open communication with parents and internalizing symptoms. *Journal of Youth and Adolescence*, *43*(11), 1861-1876.

Vargha, A., Torma, B., & Bergman, L. R. (2015). ROPstat: a general statistical package useful for conducting person-oriented analyses. *Journal of Person-Oriented Research*, *1*(1-2), 87-97. doi: 10.17505/jpor.2015.09

Wang, M. T., Eccles, J. S., & Kenny, S. (2013). Not lack of ability but more choice individual and gender differences in choice of careers in science, technology, engineering, and mathematics. *Psychological Science*, *24*(5), 770-775. doi:10.1177/0956797612458937

Wigfield, A., Eccles, J. S., Mac Iver, D., Reuman, D. A., & Midgley, C. (1991). Transitions during early adolescence: Changes in children's domain-specific self-perceptions and general self-esteem across the transition to junior high school. *Developmental Psychology*, *27*(4), 552. doi: 10.1037/0012-1649.27.4.552

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Wigfield, A. (1994). Expectancy-value theory of achievement motivation: A developmental perspective. *Educational Psychology Review*, *6*(1), 49-78. doi:10.1006/ceps.1999.1015

Wigfield, A., & Eccles, J. S. (2000). Expectancy–value theory of achievement motivation. *Contemporary Educational Psychology*, *25*(1), 68-81. doi:10.1006/ceps.1999.1015

Wigfield, A., Eccles, J. S., Yoon, K. S., Harold, R. D., Arbreton, A. J., Freedman-Doan, C., & Blumenfeld, P. C. (1997). Change in children's competence beliefs and subjective task values across the elementary school years: A 3-year study. *Journal of Educational Psychology*, *89*(3), 451. http://dx.doi.org/10.1037/0022-0663.89.3.451

Wormington, S. V., Corpus, J. H., & Anderson, K. G. (2012). A person-centered investigation of academic motivation and its correlates in high school. *Learning and Individual Differences*, *22*(4), 429-438. https://doi.org/10.1016/j.lindif.2012.03.004

Young, J. F., & Mroczek, D. K. (2003). Predicting intraindividual self-concept trajectories during adolescence. *Journal of Adolescence*, 26(5), 586-600. http://dx.doi.org/10.1016/S0140-1971(03)00058-7

Zarrett, N., Malanchuk, O., Davis-Kean, P. E., & Eccles, J. (2006). Examining the gender gap in IT by race: Young adults' decisions to pursue an IT career. In J. McGrath & W. Aspray (Eds.), *Women and Information Technology: Research on Underrepresentation* (pp. 55–88). Cambridge, MA: MIT Press.

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Figure 1

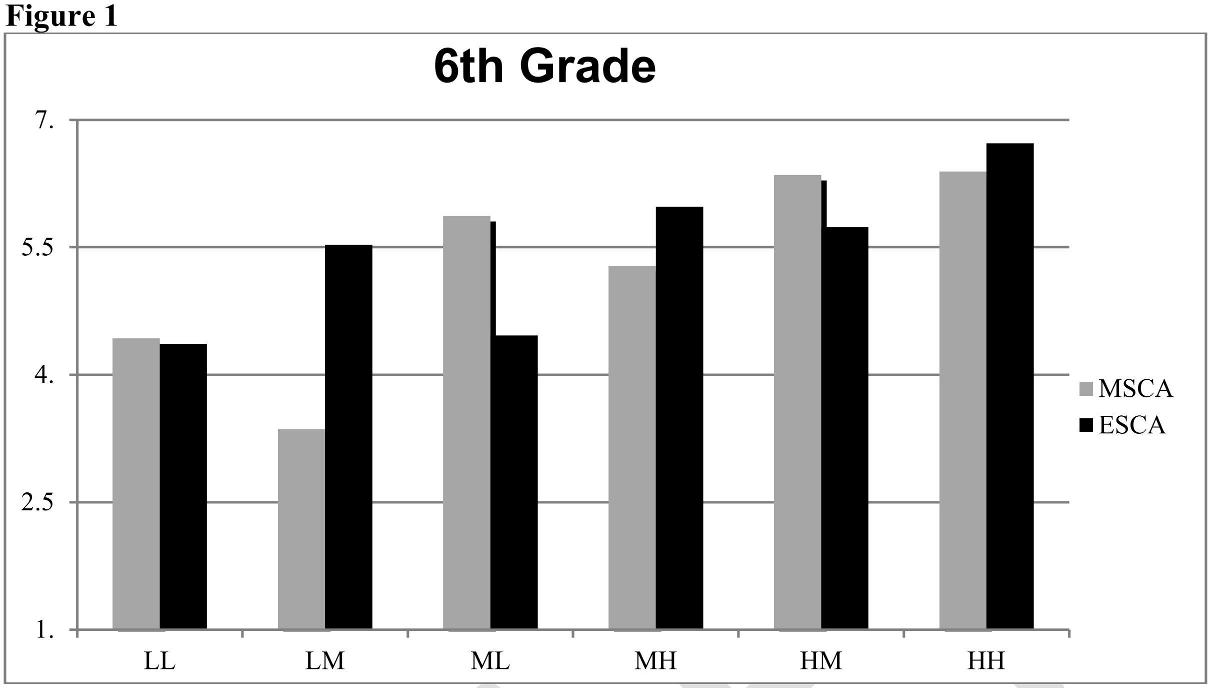

Figure 1A. Six-cluster solution for 6th Grade. MSCA=math self-concept of ability. ESCA=Englishself-concept of ability. Scores are raw scores of SCA. LL=low math-low English. LM=low math-medium English. ML=medium math-low English. MH=medium math-high English. HM=high math-medium English. HH=high math-high English.

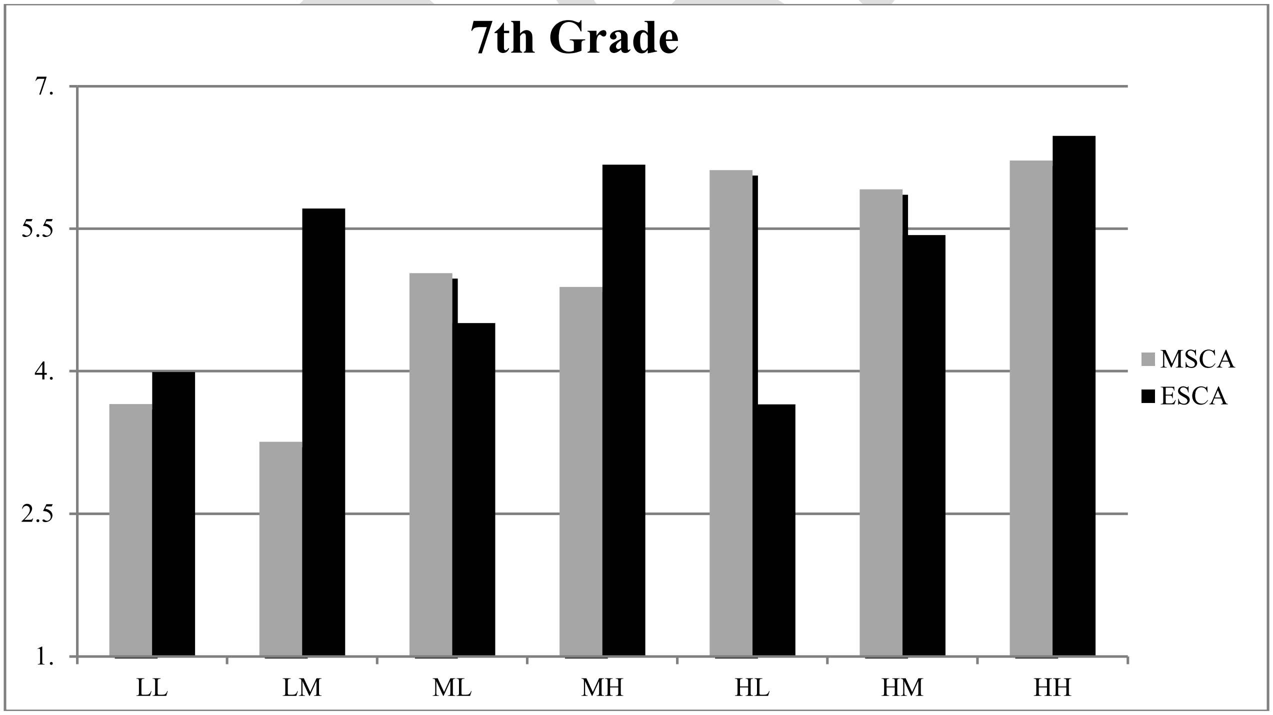

Figure 1B. Seven-cluster solution for 7th Grade. MSCA=math self-concept of ability. ESCA= English self-concept of ability. Scores are raw scores of SCA. LL=low math-low English. LM= low math-medium English. ML=medium math-low English. MH=medium math-high English. HL=high math-low English. HM=high math-medium English. HH=high math-high English.

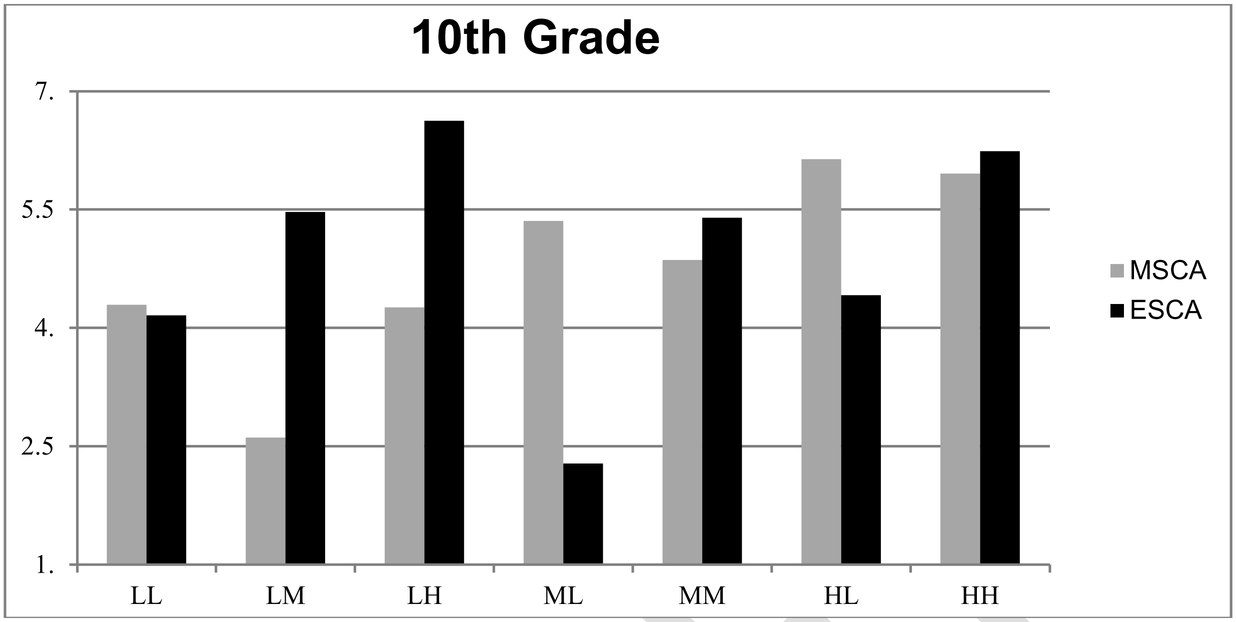

Figure 1C. Seven-cluster solution for 10th Grade. MSCA=math self-concept of ability. ESCA= English self-concept of ability. Scores are raw scores of SCA. LL=low math-low English. LM= low math-medium English. LH=low math-high English. ML=medium math-low English. MM=medium math-medium English. HL=high math-low English. HH=high math-high English.

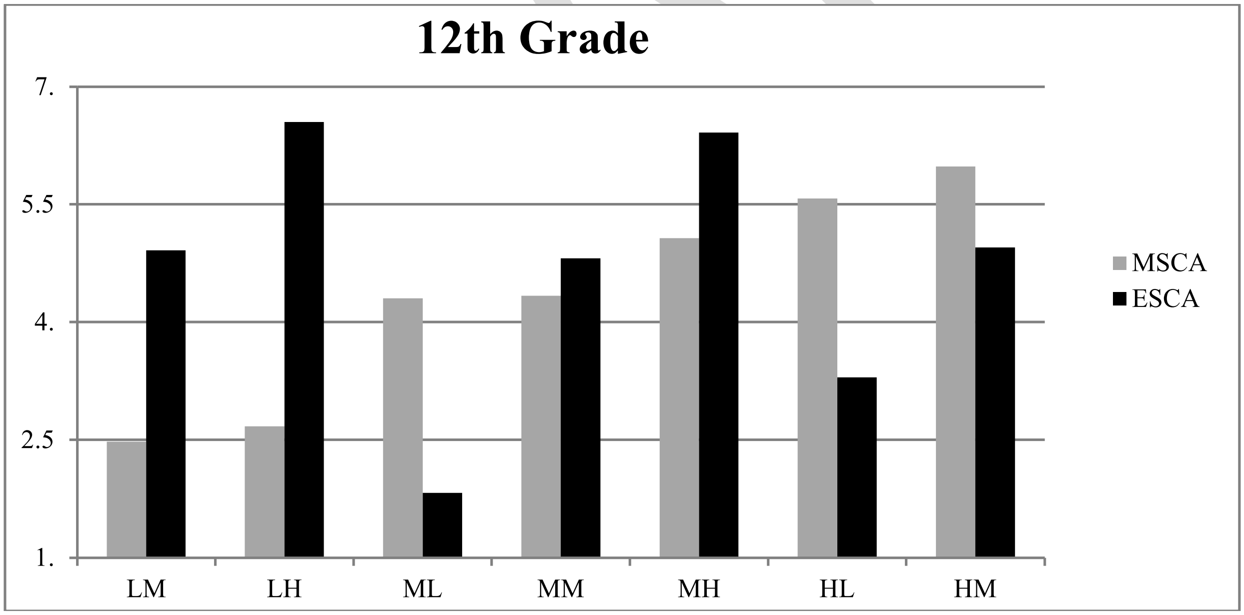

Figure 1D. Seven-cluster solution for 12th Grade. MSCA=math self-concept of ability. ESCA= English self-concept of ability. Scores are raw scores of SCA. LM= low math-medium English. LH=low math-high English. ML=medium math-low English. MM=medium math-medium English. MH=medium math-high English. HL=high math-low English. HH=high math-high English.

Table 1

College majors classified based on the level of math intensiveness

Little to no math (1)	Some math (2)	Moderate math (3)	Intensive math (4)
Humanities	Psychology	Biology	Math
English/Literature	Sociology	Pharmacy	Engineering
Philosophy	Political Science	Economics	Computer Science
International Studies	Social Work	Science (other)	Chemistry
History	Nursing	Architecture	Physics
Music/Theater/Film	Health	Physiology	Finance
Foreign Languages	Anthropology	Astronomy	Accounting
Art	Counseling	Geology	Electronics

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Table 2

Means, standard deviations, and scale alphas for all variables.

	Mean	SD	Range	Scale α	Mean for Males	Mean for females	Difference (p-value)
Math SCA 6th	5.42	1.00	1-7	0.79	5.51	5.36	0.028
Math SCA 7th	5.23	1.09	1-7	0.85	5.39	5.11	0.001
Math SCA 10th	4.87	1.23	1-7	0.86	5.01	4.76	0.008
Math SCA 12th	4.43	1.36	1-7	0.87	4.54	4.34	0.051
English SCA 6th	5.38	0.98	2.5-7	0.76	5.32	5.43	0.121
English SCA 7th	5.35	1.13	1-7	0.84	5.21	5.45	0.004
English SCA 10th	5.25	1.20	1-7	0.89	5.06	5.40	0.000
English SCA 12th	5.05	1.42	1-7	0.87	4.80	5.24	0.000
Prior math achievement	25.28	2.80	11-28	0.76	25.32	25.25	0.903
Math level of major	2.59	1.02	1-4	-	2.82	2.41	0.000

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Table 3

Correlations for all variables.

	1	2	3	4	5	6	7	8	9	10
1. Math SCA 6th	1									
2. Math SCA 7th	0.38***	1								
3. Math SCA 10th	0.34***	0.37***	1							
4. Math SCA 12th	0.38***	0.39***	0.58***	1						
5. English SCA 6th	0.29***	0.13***	0.04	0.13***	1					
6. English SCA 7th	0.23***	0.12***	0.05	0.06	0.31***	1				
7. English SCA 10th	0.11**	0.08*	-0.04	-0.03	0.34***	0.37***	1			
8. English SCA 12th	0.01	-0.08*	-0.15***	-0.26***	0.21***	0.27***	0.50***	1		
9. Female	-0.08*	-0.13***	-0.10**	-0.07	0.06	0.11**	0.14***	0.15***	1	
10. Math of major	0.20***	0.16***	0.17***	0.26***	0.04	-0.06	-0.15***	-0.19***	-0.20***	1
11. Prior math achievement	0.27***	0.31***	0.27***	0.24***	0.13***	0.21***	0.09*	0.01	-0.01	0.11**

Note. * p<0.05, ** p<0.01, *** p<0.001

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Table 4

Coefficients for SCA, Gender, and Math Achievement as Predictors of Level of Math Required by College Major

	6th Grade	7th Grade	10th Grade	12th Grade
Predictor	Level of Math Required by College Major			
Math SCA	0.18***	0.11**	0.13***	0.21***
	(0.04)	(0.04)	(0.04)	(0.04)
English SCA	-0.02	-0.08*	-0.14***	-0.12**
	(0.04)	(0.04)	(0.04)	(0.04)
Female	-0.38***	-0.36***	-0.35***	-0.35***
	(0.07)	(0.08)	(0.07)	(0.07)
Math Achievement	0.07	0.10*	0.09*	0.06
	(0.04)	(0.04)	(0.04)	(0.04)
Intercept	2.81***	2.80***	2.79***	2.79***
	(0.06)	(0.06)	(0.06)	(0.05)
R^2	0.08	0.07	0.09	0.12

Note. This table presents regression models predicting how math and English self-concept of ability, gender, and math achievement predict the level of math intensiveness of college major at each Wave. Interactions between gender and SCA variables and between math SCA and English SCA were not significant and not shown here. All independent variables are standardized. The dependent variable is unstandardized. Standard errors are in parentheses.
* $p<0.05$. ** $p<0.01$. *** $p<0.001$.

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Table 5

Cluster Centroids, Size, Homogeneity Coefficients, and Mean Math Level of College Major

Name	MSCA	ESCA	Cluster Size	HC	Mean Math level
6th Grade					
Low math-low English	4.43	4.36	136	0.61	2.47
Low math-medium English	3.36	5.53	52	1.11	2.12
Medium math-low English	5.87	4.46	152	0.51	2.61
Medium math-high English	5.28	5.98	175	0.34	2.52
High math-medium English	6.35	5.73	125	0.22	2.88
High math-high English	6.39	6.72	92	0.21	2.70
7th Grade					
Low math-low English	3.65	3.99	59	0.60	2.45
Low math-medium English	3.26	5.71	66	0.81	2.34
Medium math-low English	5.03	4.51	104	0.34	2.56
Medium math-high English	4.89	6.17	147	0.42	2.43
High math-low English	6.11	3.65	79	1.15	2.86
High math-medium English	5.91	5.43	139	0.30	2.82
High math-high English	6.22	6.48	138	0.33	2.48
10th Grade					
Low math-low English	4.29	4.16	107	0.54	2.68
Low math-medium English	2.61	5.47	91	1.20	2.41
Low math-high English	4.26	6.62	85	0.47	2.19
Medium math-low English	5.36	2.28	30	1.06	2.70
Medium math-medium English	4.86	5.39	151	0.27	2.41
High math-low English	6.14	4.41	111	0.42	3.05
High math-high English	5.95	6.24	157	0.53	2.66

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12th Grade					
Low math-medium English	2.48	4.92	65	0.84	2.33
Low math-high English	2.68	6.55	116	0.80	2.17
Medium math-low English	4.30	1.83	46	1.39	2.46
Medium math-medium English	4.34	4.81	178	0.43	2.53
Medium math-high English	5.07	6.42	132	0.74	2.45
High math-low English	5.58	3.30	84	0.82	3.14
High math-medium English	5.98	4.95	111	0.48	3.06

Note. MSCA stands for math self-concept of ability. ESCA stands for English self-concept of ability. HC stands for homogeneity coefficient.

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Table 6

Contingency Table of Cluster Stability and Movement from 6th to 12th Grade

12th 6th	LM	LH	ML	MM	MH	HL	HM
LL	20 14.7%	22 16.2%	27 19.9%	37 27.2%	7 5.2%	9 6.6%	14 10.3%
LM	7 13.5%	17 32.7%	2 3.9%	13 25.0%	10 19.2%	1 1.9%	2 3.9%
ML	14 9.2%	23 15.1%	14 9.2%	38 25.0%	19 12.5%	20 13.2%	24 15.8%
MH	14 8.0%	40 22.9%	3 1.7%	42 24.0%	35 20.0%	20 11.4%	21 12.0%
HM	4 3.2%	8 6.4%	0 0.0%	29 23.2%	22 17.6%	26 20.8%	36 28.8%
HH	6 6.5%	6 6.5%	0 0.0%	19 20.7%	39 42.4%	8 8.7%	14 15.2%

Note. Cross tabulation of 6th and 12th grade cluster stability and movement at the person level. LL=low math-low English. LM=low math-medium English. ML=medium math-low English. MM=medium math-medium English. MH=medium math-high English. HM=high math-medium English. HH=high math-high English. First row of each cluster represents the frequency of students who were in each configuration of clusters across 6th and 12th grade. Second row represents the row percentage of students who were in each configuration of 12th grade clusters from the 6th grade cluster.

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Appendix A
Self-Concept of Ability Measures for Math and English

<u>Math self-concept of ability</u>

1. How good at math are you? (1 = not at all good; 7 = very good)

2. If you were to rank all the students in your math class from the worst to the best in math, where would you put yourself? (1 = the worst; 7 = the best)

3. Compared to most of your other school subjects, how good are you at math?
(1 = much worse; 7 = much better)

<u>English self-concept of ability</u>

1. How good at English are you? (1 = not at all good; 7 = very good)

2. If you were to rank all the students in your English class from the worst to the best in English, where would you put yourself? (1 = the worst; 7 = the best)

3. Compared to most of your other school subjects, how good are you at English?
(1 = much worse; 7 = much better)

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Appendix B

Chi-squared test for Gender Differences by Cluster

6th Grade Cluster		Males	Females
Low math-low English	Observed	62	74
	ASR	0.595	-0.595
Low math-medium English	Observed	14	38
	ASR	-2.474	2.474
Medium math-low English	Observed	70	82
	ASR	0.768	-0.768
Medium math-high English	Observed	76	99
	ASR	0.038	-0.038
High math-medium English	Observed	60	65
	ASR	1.163	-1.163
High math-high English	Observed	35	57
	ASR	-1.089	1.089

Note. Overall $\chi^2 = 8.6$, df = 5, p=0.13.

ASR stands for Adjusted standardized residuals.

7th Grade Cluster		Males	Females
Low math-low English	Observed	30	32
	ASR	0.844	-0.844
Low math-medium English	Observed	24	42
	ASR	-1.193	1.193
Medium math-low English	Observed	44	65
	ASR	-0.671	0.671
Medium math-high English	Observed	42	89
	ASR	-2.867	2.867
High math-low English	Observed	49	29
	ASR	3.68	-3.68
High math-medium English	Observed	82	84
	ASR	1.801	-1.801
High math-high English	Observed	46	74
	ASR	-1.202	1.202

Note. Overall $\chi^2 = 24.89$, df = 6, p<.001***.

10th Grade Cluster		Males	Females

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Low math-low English	Observed	58	49
	ASR	2.462	-2.462
Low math-medium English	Observed	31	60
	ASR	-1.901	1.901
Low math-high English	Observed	25	60
	ASR	-2.75	2.75
Medium math-low English	Observed	15	15
	ASR	0.756	-0.756
Medium math-medium English	Observed	61	90
	ASR	-0.81	0.81
High math-low English	Observed	57	54
	ASR	1.857	-1.857
High math-high English	Observed	70	87
	ASR	0.365	-0.365

Note. Overall χ^2 = 19.13, df = 6, p=.004**.

12th Grade Cluster		Males	Females
Low math-medium English	Observed	24	41
	ASR	-1.088	1.088
Low math-high English	Observed	46	70
	ASR	-0.865	0.865
Medium math-low English	Observed	25	21
	ASR	1.561	-1.561
Medium math-medium English	Observed	81	97
	ASR	0.681	-0.681
Medium math-high English	Observed	46	86
	ASR	-2.166	2.166
High math-low English	Observed	47	37
	ASR	2.486	-2.486
High math-medium English	Observed	48	63
	ASR	-0.014	0.014

Note. Overall χ^2 = 13.66, df = 6, p=.03*.

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