Linking Early Science and Mathematics Attitudes to Long Term Science, Technology, Engineering and Mathematics Career Attainment: Latent Class Analysis with Proximal and Distal Outcomes

Abstract

There is a need to identify students’ early attitudes towards mathematics and science to better support their long-term persistence in science, technology, engineering and mathematics (STEM) careers. Seventh graders from a nationally representative sample (*N* = 2,861) were classified based on their responses to questions about their attitudes towards mathematics and science using latent class analysis. Four distinct groups of students that differed in terms of their attitudes (positive, qualified positive, indifferent, and dim) were identified. There were relationships between attitudinal group membership, demographic characteristics (gender, and ethnicity); mathematics and science achievement; and STEM career attainment. Females and underrepresented minorities were more likely to be in the positive attitude group. However, despite such these early positive attitudes, females and underrepresented minorities were less likely to be employed in a STEM career some 20 years later. Information about student interests organized in this manner can be used to better target specific interventions to support and encourage persistence in STEM careers.

*Keywords*: attitudes, STEM, achievement, mathematics, science

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There is a projected need for a workforce to fill STEM-related occupations and a projected shortage of students who have the interest and adequate preparation to fill these occupations (see for example Bureau of Labor Statistics, 2011; Langdon, McKittrick, Beede, Khan, & Doms, 2011; National Science Board, 2007, 2010a). To address this projected need and shortage, much needs to be done to identify and support students’ early interest and persistence of STEM careers.

There is a large body of literature about the importance of pre-college factors that influence students’ persistence in STEM careers (see for example, Aschbacher, Li, & Roth, 2010; Sax & Harper, 2007; Tai, Qi Liu, Maltese, & Fan, 2006). One strategy for increasing STEM persistence is to identify and support high-achieving students who have the potential to succeed the rigorous mathematics and science demands of STEM careers. Benbow (2012), for example, identified seventh and eighth graders with high achievement in mathematic. After following these early high achieving students for several decades, there is evidence indicates that these students were more likely to attain a bachelors and post-secondary STEM-related degree and persist in a STEM careers. While focusing only on the top 1% of students is one strategy, it will not necessarily fill the projected need for STEM-related occupations, particularly the diversity in STEM occupations that can support various levels of educational accomplishments; and the need to build a STEM workforce that is representative of the population in terms of gender and ethnicity.

Other strategies to identify and support a more expanded pool of students looks beyond achievement and focuses instead on paying attention to the influence of attitudes, interests and self-efficacy towards mathematics and science (see for example, Gardner, 1975; Louis & Mistele, 2012; Osborne, Simon, & Collins, 2003; Schibeci, 1984). The rationale underlying this approach is that more positive attitudes towards mathematics and science can influence interest in STEM careers and students’ motivation to achieve in the areas of mathematics and science. Attention to early attitudes towards mathematics and science provides another way to help identify students who might be interested in pursuing a STEM career.

This approach of focusing factors other than achievement such as attitudes and aspirations might be particularly useful when trying to recruit students who are not typically represented in STEM fields, females and underrepresented minorities (see for example, National Science Board, 2010b; National Science Foundation, 2011). Research suggests that achievement alone does not fully account for differences in STEM career persistence by gender or ethnicity (Riegle-Crumb et al., 2012) and that instructional opportunities and not necessarily academic potential may account for differences in student achievement by gender and ethnicity. Research based on the United States Census Bureau’s 2009 Community Survey indicates that women comprise of approximately half of the workforce but less than 25% are employed in STEM careers (Beede, Julian, Khan, Langdon, McKittrick, Khan, & Doms, 2011). Additional data from the 2000 Census suggest that this difference in STEM career employment between males and females have persisted for over a decade. These trends persist despite similar reported early interest in STEM careers (see for example, National Academy of Sciences, 2011; Russell, & Atwater, 2005; White, Altschuld, & Lee, 2006).

**Identifying Early Attitudes: A Social Cognitive Perspective on Career Development**

From a social cognitive perspective, learning occurs through the interaction of internal, personal factors (such as cognitive, affective and biological), behaviors and external, environmental factors (Bandura, 1986). This theory of learning can be used to understand and predict an individual’s behavior and has been extended to theories of how people develop interests and persist in particular careers (social cognitive career theory). Similar to social cognitive theory, the social cognitive career theory highlights the importance and mutual influence of self-efficacy (personal beliefs about one’s ability to succeed), outcome expectations (personal beliefs about the outcome of performing particular behaviors) and personal goals (Betz & Hackett, 2006; Lent, Brown, & Hackett, 1994, 1996). These social cognitive factors help individuals regulate their own career behavior by influencing career-related attitudes and interests, choices and attainment (Lent & Brown, 1996).

Given the mutual influence of these factors, this theory places importance on early attitudes and interests in activities with have potential career relevance because these activities will influence future career interests. For example, consider a children who experiment with different types of materials such as paper, fabric or rubber learn about characteristics of characteristics of materials (waterproof, strong, transparent) and build with these different materials with encouragement from others (parents and other family members, teachers, peers). These types of supportive experiences reinforce future choices such as a career as a materials science engineer. Children without this type of supportive experience are less likely to develop interest in these types of activities and are less likely to pursue careers that involve these types of interests. Social cognitive career theory posits that children who have experience and feedback related to particular types of activities are likely to not only improve their skills in these areas but also to form a sense of their efficacy toward these types of activities.

In terms of career development related to STEM careers, students who have experiences related to STEM are likely to develop positive attitude toward mathematics and science and perceive that they can succeed in these careers that value these types of skills and experiences. There is theoretical support for focusing on student early attitudes toward mathematics and science and how their understanding of how these subjects are relevant to their future career aspirations influence decisions to pursue STEM careers. However, there is less agreement of how to empirically identify students with early interests.

This study builds on existing literature by examining a method to classify student attitudes towards mathematics and science in seventh grade. This study explores differences in student attitudes by gender, ethnicity and achievement and relates these differences to whether or not these students were employed in a STEM career by their mid-30’s. This study uses a methodology that helps make sense of underlying differences in student mathematics and science attitudes and links these early attitudes to STEM career attainment. In doing so, this study contributes to the literature in the following ways: includes longitudinal data of a national sample of seventh graders, includes mathematics and science attitude variables, and includes outcome of STEM career attainment.

Information from this study can be used to help target programs or interventions to particular groups of students. For example, there might be a group of seventh graders who express positive attitudes toward mathematics but not science. Programs could be targeted to encourage interest in science such as field trips to local science-related business settings to learn more about what science-related careers exist or summer programs that provide opportunities for students to conduct research with undergraduates majoring in science-related fields. Or suppose there is a group of students that express positive attitudes towards mathematics and science, programs could be targeted to this group of students to ensure that this interest is supported throughout high school through frequent, meaningful experiences with science and mathematics. Early identification of students with different interests in science and mathematics could be the first step in providing more specific and informed support to increase the number and quality of students interested in pursuing STEM careers.

**Method**

**Sample**

This sample includes participants from the Longitudinal Study of American Youth (LSAY). The LSAY is a national sample of public school students in 1987 who are now in their late-30s. The LSAY was funded by the National Science Foundation in 1986 to examine the development of student achievement in middle and high school and the relationship of those patterns to career choices. The students included in this particular study were from the seventh grade cohort. The cohort consists of students from 52 middle schools across the United States in 1987. Approximately 60 students were randomly selected from each school. The sample is predominantly White (70%) with approximately equal numbers of females (48%) and males (52%). The sample included 9% Hispanic, 11% African American, 4% Asian, and 2% Native American (5% of students did not indicate any race/ethnicity). Thirty-one percent of the students in the sample had at least one parent who completed college, while the other 69% did not. In 2007, more than 95% of the original sample completed a questionnaire about their educational and occupational outcomes (Miller, 2010). These same students were surveyed in 2007 about their career choices (Miller & Kimmel, 2012). This particular study includes data from students who completed an attitudinal questionnaire and mathematics and science achievement tests in 1987 and career attainment in 2007 (*N* = 2,861).

**Measures**

**Mathematics and science attitudes**. Ten items related to mathematics and science attitudes were included (Table 1). These items were selected based on prior literature on social cognitive career theory to reflect student enjoyment of mathematics and science, perceived usefulness and importance of mathematics and science in the future (Lent & Brown, 2006).

In particular, social cognitive career theory indicates that these constructs should be considered: self-efficacy, outcome expectations, and interests, goals. To measure self-efficacy, one item was selected, “I enjoy math”. There were two items selected to measure outcome expectations, “Math is useful in everyday problems” and “Math helps a person think logically” and two items selected to measure interests and goals, “It is important to know math to get a good job” and “I will use math in many ways as an adult.”

This study includes items about mathematics and science attitudes because most STEM careers require both mathematics and science knowledge and research suggests that attitudes are content specific and that measures should be tailed to the specific domain (Bandura, 1986; Hackett & Betz, 1981; Lent & Brown, 2006). The items in science are analogous to the items in mathematics. For example, one item related to mathematics attitudes is, “Math is useful in everyday problems” and the item related to science attitudes is, “Science is useful in everyday problems.” The response options were: strongly agree, agree, not sure, disagree, strongly disagree. These options were coded so that a higher value (5) indicates stronger agreement or more positive attitudes and a lower value (1) indicates less agreement or less positive attitudes.

**Mathematics and science achievement**. Student mathematics achievement was assessed in the fall of seventh (*M* = 50.47, *SD* = 10.20) and eighth grade (*M* = 53.73, *SD* = 11.09). The scores were calculated using an Item Response Theory model (Lord, 1980), with a scale ranging from 0 to 100. Each test consisted of items from the National Assessment of Educational Progress and was designed to measure basic skills, algebra, geometry, and quantitative literacy. Seventh grade achievement is considered a covariate and eighth grade achievement is considered a proximal outcome.

Student science achievement was assessed in the fall of eighth grade (*M* = 54.05, *SD* = 11.16). Similar to the mathematics achievement scores, the science scores were calculated using an Item Response Theory model. The scale ranged from 0 to 100 with items also selected from the NAEP around content areas such as biology, physics and environmental sciences. Eighth grade science achievement is considered a proximal outcome.

**STEM career attainment**. In the 2007 questionnaire, respondents were asked about the industry of their current occupation. LSAY created a dichotomous variable to indicate whether or not the respondent was currently employed in a STEM occupation (such engineering) or not. The particular definition of a STEM career used as an outcome variable in this study includes the full range of STEM occupations but excludes social science occupations. Fifteen percent (*n* = 275) of the sample was employed in a STEM or STEM support occupation. STEM career attainment is used as a distal outcome.

**Demographics**. Students self-reported their gender and ethnicity. There were roughly similar number of males (51%) and females (49%) included. A dichotomous variable of ethnicity was created: White and Asian (not underrepresented minority); and African American, Hispanic/Latino, and Native American (underrepresented minorities). This grouping is included because underrepresented minority students have lower representation in STEM careers compared to other students (see for example, Huang, Taddese, & Walter, 2000). This sample includes 77% White and Asian students and 23% underrepresented minority students.

**Analysis**

Data was analyzed using Latent Class Analysis (LCA), an analytic technique used to classify groups of individuals into latent classes based on their responses to the set of indicators (Bartholomew, 1987; Collins & Lanza, 2010; Goodman, 1974; Heinen, 1996; Lazarsfeld & Henry, 1968; Muthén, 1992, 2001). LCA is an exploratory multivariate analysis—that is, there is no apriori specification of the number or type of classes that emerge. LCA differs from the more commonly used factor analysis in that factor analysis clusters items and LCA clusters individuals.

Traditionally, LCA models are fit in a series of steps. First, a one-class model is fit and then the number of classes is increased. The fit of each new model that differs by the specification on one more class is compared to the previous model. With parsimony in mind, a model with the greater number of classes is selected only if increasing the number of classes results in conceptually meaningful groupings and provides good statistical fit. In the present analysis, once the number of classes was decided upon, covariates (gender, race, and previous math achievement) were included in the model (Nylund-Gibson & Masyn, 2011) and the means of the distal outcome was estimated for each class using pseudoclass draws. Pseudoclass draws are a preferred method for comparing the mean of distal outcomes compared to say a regression, because this method takes into account the fact that individuals are not assigned with 100% certainly into each of the latent classes (Clark & Muthén, 2009). The *p-*values from a series of pairwise Wald tests (e.g., “auxiliary (e)” in M*plus*) were used to test for significant differences in means across the classes based on the means from the pseudoclass draws (seeMuthén & Asparouhov, 2010). There are several outcomes compared. Eighth grade mathematics and science achievement are considered proximal outcomes because this was measured a year after the attitudinal data was collected. STEM career attainment is considered a distal outcome because this was measured twenty years after the attitudinal data was collected. It is hypothesized that attitudinal group differences are related to both the proximal and distal outcomes.

In this LCA application, several indicators of model fit were used since there is no single statistical indicator is recommended to assess model fit. We used a combination of statistical indicators and substantive theory to decide on the best fitting model (Nylund, Asparouhov, & Muthén, 2007; Masyn, 2012). The Bayesian Information Criterion (BIC; Schwartz, 1978), the most commonly used and trusted fit indices for model comparison was used, where lower values of the BIC indicated better fit. Along with the BIC, we compared models that differed in the number of classes using the Lo-Mendell-Rubin (LMR) and the bootstrap likelihood ratio test (BLRT) to evaluate if adding an additional class significantly improved model fit (for more on these fit indices see Nylund et al. [2007]). The entropy of the final model selected is reported in the text, but not used for model fit because it describes the overall classification of students into the latent classes. Entropy ranges between 0 and 1, where 1 is perfect classification and values approaching 1 indicate clear delineation of classes (Celeux & Soromenho, 1996).

**Results**

The results are divided into three sections: (a) identifying the attitudinal profiles (latent classes), (b) assessing attitudinal group differences with respect to the covariates, and (c) assessing the attitudinal profiles with respect to proximal and distal outcomes.

**Understanding Math and Science Attitude Profiles**

As described before, a series of LCA models were fit specifying 1-8 latent classes. For each model, fit statistics were collected and used to help inform the decision about how many classes were sufficient to describe the heterogeneity in student attitudes towards math and science (Table 2). The lowest value of the BIC (33330.37) was for the 6-class model, though there was not a large change in the BIC after the 4-class model. The significant *p*-value of the LMR indicated that a 7-class model fit the data well. There was never a non-significant *p*-value for the BLRT, so this did not inform our decision.

Given these results, the 4-class and 5-class solutions were studied for interpretability. Four of the five classes were consistent across the two models, and the fifth class was a not easily interrupted class that not result in any further information gained about the attitudinal profiles. For the sake of model parsimony and interpretability, the 4-class model is preferred. Given the statistical support of the 4-class model, and the substantive plausibility of the solution, this model was selected as the final model. The entropy for this model was .79, an acceptable value.

The item profile plot presented in Figure 1 is for LCA model with four latent classes. Along the *x*-axis are the 10 math and science attitude variables and along the *y*-axis is the probability of endorsing a given item. These profile plots are used to understand and label the latent classes that emerge in LCA. All of the attitudinal items are coded so that 1 indicates a student endorsed the given item. When interpreting and labeling the emergent latent classes, it is important to consider both the probability of a class endorsing a given attitudinal item, as well has how items differentiate the classes.

The four classes were labeled: *Positive*, *Qualified Positive*, *Indifferent* and *Dim*. As seen in Figure 1, the *Positive* group (25%) indicated consistently positive attitudes towards mathematics and science as evidenced by a high probability of endorsing the mathematics and science attitudinal items (labeled with diamonds in Figure 1). The *Qualified Positive (*squares in Figure 1) group (31%) had a high probability of endorsing the positive attitudes towards mathematics, but had a low probability of endorsing the science items. Their attitudes towards mathematic were lower than the *Positive* group and higher than the *Indifferent* group (25%). However, the science attitudes of the group we labeled *Qualified Positive* (circles in the figure) were lower than the *Indifferent* group. The smallest group (19%) was labeled, *Dim* due to their consistently less positive attitudes towards mathematics and science (“X” in the figure).

**Assessing Attitudinal Group Differences With Respect to Covariates**

Covariates included in the model, and the latent class variable was regressed on the covariates. Since the latent class variable is a categorical latent variable, the regression of this variable on the covariate is a multinomial logistic regression, and instead of interpreting regression coefficients, we interpret logits. We selected the *Positive* class, the group of students with positive math and science attitudes, to be our comparison group, and compared the other three classes with respect to the covariates. Specifically, we compare the *Positive* class to the three groups with respect to their values on the covariate. Table 3 presents the logit parameters, standard errors, corresponding *t*-value, and odds ratio for each comparison.

Comparing the students in the, *Qualified Positive* class to the *Positive* class, we find several significant differences.Specifically, compared to the *Positive* class, minority students are less likely to be in the *Qualified Positive* class (-.48, *p* <.05, OR = 0.62), and female students are more likely to be in the *Qualified Positive* class (.83, *p* <.05, OR = 2.28). Lastly, compared to the *Positive* class, students with higher math scores are less likely to be in *Qualified Positive* class (-.02, *p* <.05, OR = .98), though given the odds ratio close this result is not considered a strong one.

Comparing the students in the *Indifferent* class to the *Positive* class, there are no differences in the prevalence of minority students or gender among these two classes. That is, students that are underrepresented minorities (.02, *p* >.05, OR = 1.0) or female (.28, *p* >.05, OR = .32) are equally likely to in the *Positive* and *Indifferent* classes. There was a small effect of prior math achievement when comparing these two classes. Specifically, as math scores increases, students were slightly less likely to be in the *Indifferent* class compared to the *Positive* class (-.06, *p* <.05, OR = .94).

Lastly, comparing *Dim* to *Positive* class there were differences on all three covariates. That is, students that were minority were less likely to be in *Dim* class compared to *Positive* class (-.40, *p* <.05, OR = .67) and females students are more likely to be in *Dim* compared to *Positive* class (.56, *p* <.05, OR = 1.75). Similar to other class results, students with higher math scores were less likely to be in *Dim* class compared to *Positive* class (-.06, *p* <.05, OR = .95), though this was a small effect.

**Predicting Proximal Outcomes Based on Attitudinal Grouping**

To explore how important math and science attitudes in seventh grade are in predicting academic outcomes in the following school year, we included two variables: eighth grade mathematics and science achievement and allowed the means to vary across the four groups.

With respect to eighth grade mathematics, the results indicated that there were significant differences in the mathematics scores in eighth grade across the test scores (χ2(3) = 65.06, *p* < .001). As reported in Table 4, students in *Positive* class had the highest mathematics performance in eighth grade which also was significantly higher compared to the other three classes. The next highest mean eighth grade mathematics achievement were students in *Qualified Positive* class who were significantly lower than students in the *Positive* class. Students in *Indifferent* and *Dim* classes were significantly lower than *Positive* and *Qualified Positive* class, but were similar to each other.

The relationship between the four attitude groups and eighth grade science performance showed as similar pattern to eighth grade mathematics. Results indicated that there was a overall mean difference in the science scores across class (χ2(3) = 38.44, *p* < .001). Students in the *Positive* class had the highest science performance (see Table 4) which was significantly higher than all of the other classes. The next highest class was the *Qualified* *Positive*, which was significantly different from the *Indifferent* class, which had the third highest science mean. The *Indifferent* and *Dim* class were not significantly different from each other in terms of their science performance in eighth grade.

**Predicting Distal Outcome Based on Attitudinal Groupings**

STEM career attainment is considered a long-term, distal outcome in that this occurred over two decades after the seventh grade attitudinal and achievement data was collected. A Wald test was used to compare all between-class comparisons to see which attitudinal group was most likely to eventually go into a STEM career. For this distal outcome, we see an interesting result (Table 4). Students in the *Positive* class were the most likely among the four classes to go on to a STEM career. Specifically, approximately 13% of these students ended up in a STEM related career. Students in the *Positive* class were more likely to be in a STEM career compared to the students in the other three classes. Following are the *Qualified Positive* and *Indifferent* students, for which approximately 8% of the students in these classes went into a STEM career. And lastly, only 4% of the students in the *Dim* class, those who have the lowest math and science attitudes, were the least likely to go into a STEM career.

Combining the covariate and distal analysis results provides an interesting story. As expected, students with high math and science attitudes have the highest subsequent math scores and are more likely to eventually successfully pursue a STEM career. The covariate results indicated that minority and female students were more likely to be in this class compared to *Qualified Positive* and *Indifferent* classes, which is unexpected given the underrepresentation of these groups in STEM career. However, looking closer into the *Positive* class, the group of students most likely to go into a STEM career, only 4% of these students were underrepresented minorities and 10% were female. Even though this group of students is more likely to pursue a career in STEM and females and underrepresented minorities were more likely to be in this group compared to the other three groups, females and underrepresented minorities in this group were less likely than males and Whites and Asians to pursue a STEM career.

**Discussion**

Using latent class analysis, we found that seventh grade underrepresented minority students were not only similar in their attitudes towards mathematics and sciences compared to males and White and Asian students but were actually more likely to be in the *Positive* group compared to other students. However, prior research on STEM careers foreshadows how this story ends. Despite this initial early interest in mathematics and science, data from this sample also indicates that even females and underrepresented minority students in the group of students with the most positive early attitudes towards mathematics and science, there are still far fewer females and underrepresented students who actually persisted in a STEM career.

While attitudes towards mathematics and science do not fully capture the interrelated factors that influence students decisions to pursue STEM career, this is an aspect that malleable and influenced by factors such as teacher and family support (Archer, DeWitt, Osborne, Dillon, Willis, & Wong, 2012; Aschbacher, Li, & Roth, 2010; DeWitt, Archer, Osborne, Dillon, Willis, & Wong, 2011; Osborne, Simon, & Collins, 2003). Knowing that females and underrepresented minorities opt out of STEM careers at higher rates than males and females despite these early positive attitudes towards mathematics and science raises issues of when these attitudes start to decline. Future research using longitudinal data can help identify at what time point this interest starts to dip and gaps between females/males, underrepresented minorities/white and Asians become more pronounced.

This study does not attempt to explain these gaps in STEM career attainment for females and underrepresented minorities. Instead, this study applies a method to identify early interests in science and mathematics to allow for more targeted interventions that can provide the sort of deep, meaningful engagement with science and mathematics that will encourage more students to pursue careers in these areas. While we do not expect all students in the *Positive* group to persist in a STEM careers; we also do not expect none of the students in the *Dim* group to persist in STEM careers either. Rather, this modeling approach provides a way to organize information about student attitudes in a way that helps target support to different types of students. There is great diversity in STEM careers –careers that all require mathematics and science knowledge but span the full range of level of formal educational attainment. For example, a STEM career includes a materials science engineer who synthesizes new nanoscale materials to address challenges in the area of solar power generation and medical laboratory technicians and a clinical laboratory technician who matches blood for transfusions (Solberg, Kimmel, & Miller, 2012). Even if students to not pursue STEM careers, encouraging and supporting more positive attitudes towards mathematics and science nurtures the growth of a more informed public that supports, appreciates and is energized by STEM innovations.

References

Archer, L., DeWitt, J., Osborne, J., Dillon, J., Willis, B., & Wong, B. (2012). Science aspirations, capital, and family habitus: How families shape children’s engagement and identification with science. *American Educational Research Journal*, *49*(5), 881-908.

Aschbacher, P. R., Li, E., & Roth, E. J. (2010). Is science me? High school students’ identifies, participation and aspirations in science, engineering and medicine. *Journal of Research in Science Teaching*, *47*, 564-582.

Bandura, A. (1986). *Social foundations of thought and action: A social cognitive theory*. Englewood Cliffs, NJ: Prentice Hall.

Bartholomew, D. J. (1987). *Latent variable models and factor analysis*. New York: Oxford University Press.

Beede, D., Julian, T., Langdon, D., McKittrick, G., Khan, B., & Doms, M. (2011). *Women in STEM: A gender gap to innovation* (ESA Issue Brief #04-11). Washington, DC: U.S. Department of Commerce.

Benbow, C. P. (2012). Identifying and nurturing future innovators in science, technology, engineering, and mathematics: A review of findings from the study of mathematically precocious youth. *Peabody Journal of Education*, *87*, 16-25.

Betz, N. E., & Hackett, G. (2006). Career self-efficacy theory: Back to the future. *Journal of Career Assessment*, *14*, 3-11.

Bureau of Labor Statistics. (2011). *Occupational outlook handbook* (2010-2011 ed.). Washington, DC: Author.

Celeux, G., & Soromenho, G. (1996). An entropy criterion for assessing the number of clusters in a mixture model. *Journal of Classification*, *13*(2), 195-212.

Clark, S., & Muthén, B. O. (2009) Relating latent class analysis results to variables not included in the analysis. Manuscript submitted for publication. Available for download at http://www.statmodel.com/download/relatinglca.pdf

Collins, L. M., & Lanza, S. T., (2010). Latent class and latent transition analysis: With applications in the social, behavioral, and health sciences. New York: Wiley.

DeWitt, J., Archer, L., Osborne, J., Dillon, J., Willis, B., & Wong, B. (2011). High aspirations but low progression: The science aspirations-careers paradox among minority ethnic students. *International Journal of Science and Mathematics Education*, *9*(2), 243–271.

Gardner, P. L. (1975). Attitudes to science. *Studies in Science Education*, *2*, 1–41.

Goodman, L. A. (1974). Exploratory latent structure analysis using both identifiable and unidentifiable models. *Biometrika, 61*, 215-231.

Hackett, G., & Betz, N. E. (1981). A self-efficacy approach to the career development of women, *Journal of Vocational Behavior*, *18*, 326-336.

Heinen, T. (1996). *Latent class and discrete latent trait models: Similarities and differences*. Thousand Oaks, CA: Sage Publications.

Huang, G., Taddese, N., & Walter, E. (2000). *Entry and persistence of women and minorities in college science and engineering education* (No. NCES 2000601). Washington, D.C.: National Center for Education Statistics.

Langdon, D., McKittrick, G., Beede, G., Khan, B., & Doms, M. (2011). *STEM: Good jobs now and for the future* (ESA Issue Brief #03-11). Washington, DC: U.S. Department of Commerce.

Lazarsfeld, P. F., & Henry, N. W. (1968). *Latent structure analysis*. New York: Houghton Mifflin.

Lent, R. W., & Brown, S. D. (1996). Social cognitive approach to career development: An overview. *Career Development Quarterly*, *44*(4), 310-321.

Lent, R. W., & Brown, S. D. (2006). On conceptualizing and assessing social cognitive constructs in career research: A measurement guide. *Journal of Career Assessment*, *14*, 12-35.

Lent, R. W., Brown, S. D., & Hackett, G. (1994). Toward a unifying social cognitive theory of career and academic interest, choice, and performance. *Journal of Vocational Behavior*, *45*, 79-122.

Lent, R. W., Brown, S. D., & Hackett, G. (1996). Career development from a social cognitive perspective. In D. Brown & L. Brooks (Eds.), *Career choice and development* (pp. 373-421). San Francisco, CA: Jossey-Bass.

Lord, F. M. (1980). *Applications of item response theory to practical testing problems*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Louis, R., & Mistele, J. (2012). The differences in scores and self-efficacy by student gender in mathematics and science. *International Journal of Science and Mathematics Education*, *10*(5), 1163-1190.

Masyn, K. (2012). Latent class analysis and finite mixture modeling. In T. Little (Ed.), *The Oxford handbook of quantitative methods in psychology* (Vol. 2, pp. 375-393). Oxford, UK: Oxford University Press.

Miller, J. D. (2010). *Longitudinal Study of American Youth, 1987-1994, and 2007*. Ann Arbor, MI: Inter-university Consortium for Political and Social Research.

Miller, J. D., & Kimmel, L. G. (2012). Pathways to a STEMM profession. *Peabody Journal of Education*, *87*, 26-45.

Muthén, B. O. (1992). Latent variable modeling in epidemiology. *Alcohol Health and Research World, 16*, 286-292.

Muthén, B. O. (2001). Latent variable mixture modeling. In G. A. Marcoulides and R. E. Schumacker (Eds.), *New Development and Techniques in Structural Equation Modeling* (pp. 1-33). Mahwah, NJ: Lawrence Erlbaum Associates.

Muthén, B. O., & Asparouhov, T. (2010). Wald Test of Mean Equality for Potential Latent Class Predictor in Mixture Modeling. Mplus Technical Appendix. Retrieved from http://www.statmodel.com/download/meantest2.pdf

National Academy of Sciences. (2011). *Expanding underrepresented minority participation: America's science and technology talent at the crossroads*. Washington, DC: Author.

National Science Board. (2007). *National action plan for addressing the critical needs of the U.S. science, technology, engineering and mathematics education system* (NSB-07-114). Arlington, VA: National Science Foundation.

National Science Board. (2010a). *Science and engineering indicators 2010*. Arlington, VA: National Science Foundation.

National Science Board. (2010b). *Preparing the next generation of STEM innovators: Identifying and developing our nation’s human capital*. Arlington, VA: National Science Foundation.

National Science Foundation. (2011). *Women, minorities, and persons with disabilities in science and engineering: 2011* (NSF 11–309). Arlington, VA: National Science Foundation.

Nylund, K. L., Asparouhov, T., & Muthén, B. O. (2007). Deciding on the number of classes in latent class analysis and growth mixture modeling: A Monte Carlo simulation study. *Structural Equation Modeling: A Multidisciplinary Journal, 14*, 535–569.

Nylund-Gibson, K. L., & Masyn, K. E. (2011, April). Including auxiliary variables in latent class analysis*.* In K. Nylund-Gibson (Chair), *An overview of latent class analysis: Application and issues*. Symposium conducted at the 91st Annual Meeting of the Western Psychological Association, Los Angeles, CA.

Osborne, J., Simon, S., & Collins, S. (2003). Attitudes towards science: A review of the literature and its implications. *International Journal of Science Education*, *25*(9), 1049–1079.

Riegle-Crumb, C., King, B., Grodsky, E., & Muller, C. (2012). The more things change, the more they stay the same? Prior achievement fails to explain gender inequality in entry into STEM college majors over time. *American Educational Research Journal*, *49*(6), 1048-1073.

Russell, M. L., & Atwater, M. M. (2005). Traveling the road to success: A discourse on persistence throughout the science pipeline with African American students at a predominantly White institution. *Journal of Research in Science Teaching*, *42*(6), 691-715.

Sax, L. J., & Harper, C. E. (2007). Origins of the gender gap: Pre-college and college influences on differences between men and women. *Research in Higher Education*, *48*(6), 669-694.

Schibeci, R. A. (1984). Attitudes to Science: An update. *Studies in Science Education*, *11*, 26–59.

Schwartz, G. (1978). Estimating the dimension of a model. *The Annals of Statistics, 6,* 461–464.

Solberg, V. S., Kimmel, L. G., & Miller, J. D. (2012). Pathways to STEMM support occupations. *Peabody Journal of Education*, *87*, 77-91.

Tai, R. H., Qi Liu, C., Maltese, A. V., & Fan, X. (2006). Planning early for careers in science. *Science*, *312*(5777), 1143–1144.

White, J. L., Altschuld, J. W., & Lee, Y. (2006). Persistence of interest in science, technology, engineering, and mathematics: A minority retention study. *Journal of Women and Minorities in Science and Engineering*, *12*, 47-64.

Table 1

*Descriptives of Mathematics and Science Attitude Items*

|  |  |  |  |
| --- | --- | --- | --- |
|  | *N* | *M* | *SD* |
| I enjoy math | 2875 | 3.71 | 1.18 |
| Math is useful in everyday problems | 2819 | 3.87 | 1.01 |
| Math helps a person think logically | 2160 | 3.39 | 0.78 |
| It is important to know math to get a good job | 2824 | 4.05 | 0.96 |
| I will use math in many ways as an adult | 2829 | 4.04 | 0.96 |
| I enjoy science | 2857 | 3.55 | 1.25 |
| Science is useful in everyday problems | 2804 | 3.26 | 1.09 |
| Science helps a person think logically | 2809 | 3.47 | 1.04 |
| It is important to know science to get a good job | 2828 | 3.28 | 1.09 |
| I will use science in many ways as an adult | 2859 | 3.42 | 1.13 |

Table 2

*Summary of Latent Class Analysis Fit Indices with 1-8 Latent Classes*

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| *Classes* | *LL* | *# of parameters* | *BIC* | *ABIC* | *VLMR p-value* | *BLRT p-value* | *Entropy* |
| 1 | -19319.60 | 10 | 38719.49 | 38687.72 | -- | -- | -- |
| 2 | -17198.43 | 21 | 34565.46 | 34498.74 | 0.00 | 0.00 | 0.80 |
| 3 | -16782.26 | 32 | 33821.44 | 33719.76 | 0.00 | 0.00 | 0.75 |
| 4 | -16587.89 | 43 | 33521.03 | 33384.40 | 0.00 | 0.00 | 0.79 |
| 5 | -16479.34 | 54 | 33392.24 | 33220.66 | 0.00 | 0.00 | 0.73 |
| 6 | -16404.25 | 65 | 33330.37 | 33123.84 | 0.00 | 0.00 | 0.74 |
| 7 | -16368.47 | 76 | 33347.13 | 33105.65 | 0.00 | 0.00 | 0.75 |
| 8 | -16337.31 | 87 | 33373.12 | 33096.69 | 0.23 | 0.00 | 0.72 |

Table 3

*Log Odds Coefficients and Odds Ratio for Four-Class Model With Minority, Status, and Prior Math Achievement as Covariates, Using the Positive Class as the Comparison Groups*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | *Logit* | *SE* | *est/SE* | *Odds Ratio* |
| *Qualified Positive* |  |  |  |  |
| Underrepresented minority | -0.48\*\*\* | 0.17 | -2.87 | 0.62 |
| Female | 0.83\*\*\* | 0.13 | 6.43 | 2.28 |
| Mathematics achievement | -0.02\*\* | 0.01 | -2.72 | 0.98 |
| *Indifferent* |  |  |  |  |
| Underrepresented minority | 0.02 | 0.23 | 0.10 | 1.02 |
| Female | 0.28 | 0.15 | 1.83 | 1.32 |
| Mathematics achievement | -0.06\*\*\* | 0.01 | -5.17 | 0.94 |
| *Dim* |  |  |  |  |
| Underrepresented minority | -0.40\* | 0.18 | -2.22 | 0.67 |
| Female | 0.56\*\*\* | 0.13 | 4.19 | 1.75 |
| Mathematics achievement | -0.06\*\*\* | 0.01 | -5.16 | 0.95 |

*Note*. Comparison group is “Positive”.

\**p* < .05. \*\**p* < .01. \*\*\**p* < .001.

Table 4

*Comparison of Proximal and Distal Outcomes*

|  |  |  |  |
| --- | --- | --- | --- |
| *Attitudinal Classes* | *Eighth Grade Math* | *Eighth Grade Science* | *STEM Career* |
| Positive | 56.92 (0.50)a | 56.80 (0.50)a | 0.13 (0.02)a |
| Qualified Positive | 55.28 (0.41)b | 55.46 (0.42)b | 0.08 (0.01)b |
| Indifferent | 50.86 (0.52)c | 52.05 (0.53)c | 0.08 (0.02)b |
| Dim | 51.64 (0.52)c | 51.81 (0.55)c | 0.04 (0.01)c |

*Note.* Means that do not share subscripts differ at *p* < .05.



*Figure 1*. Item probability profiles.