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| **Reports** (up to ~2500 words including references, notes and captions or ~3 printed pages) present important new research results of broad significance. Reports should include an abstract, an introductory paragraph, up to four figures or tables, and about 30 references. Materials and Methods should usually be included in [supplementary materials](http://www.sciencemag.org/site/feature/contribinfo/prep/prep_online.xhtml), which should also include information needed to support the paper's conclusions. |

The Importance of Early Attitudes Towards Math and Science

Students with consistently positive attitudes toward mathematics and science were more likely to pursue careers in science and be more supportive of science while adolescents with negative attitudes toward mathematics and science were more likely to have consistently negative attitudes toward science and be less supportive of science at the end of twelfth grade, emphasizing the importance of encouraging and supporting early positive attitudes.

There are multiple goals to science education reforms such as the Next Generation Science Standards. One goal is to increase the number of qualified students who are interested in pursuing careers in science (Graham, Frederick, Byars-Winston, Hunter, & Handelsman, 2013). Another goal is to increase the science and technological literacy of all students to create a more informed general public that actively engages and supports scientific innovation and discovery (Feinstein, Allen, & Jenkins, 2013). Central to these multiple goals is improving all students’ attitudes towards science and mathematics (Osborne, Simon, & Collins, 2003).

There is evidence that there is a decline in student attitudes toward science (Breakwell & Beardsell, 1992; Hadden & Johnstone 1983; Harvey & Edwards 1980; Johnson 1987; Simpson & Oliver 1985; Smail and Kelly, 1984; Yager and Penick 1986) and that student attitudes shift depending on factors such as the who is teaching science and what sort of science they are teaching (Havard, 1996; Osborne & Collins, 2000; Whitfield, 1980). There is also evidence that student attitudes toward science and mathematics are related to interest in STEM careers and academic behaviors related to science and mathematics (references). Despite efforts to improve interest in science such as professional development opportunities for science teachers, we know little about the long-term implications of these efforts to address declining student attitudes. This study explores how enduring and persistent early student attitudes are toward mathematics and science using a nationally representative, longitudinal data. In doing so, we addressed the following questions: 1) How stable are student attitudes towards mathematics and science from seventh through twelfth grade?; 2) Do students who are typically underrepresented in STEM fields change their attitudes toward mathematics and science more or less compared to other students?; and 3) Are changes in attitudes related to student STEM career persistence, and student interest and support for science-related issues? This study identifies grade levels where student attitudes might be particularly vulnerable to shifting and the extent to which attitudes towards mathematics and science are persistent for particular groups of students.

**Survey and Analysis**

We used the Longitudinal Study of American Youth (LSAY) for this study (Miller, 2010). 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. Annual data was collected starting in seventh grade and continuing one year beyond high school. Follow-up data collection efforts started in 2005 (when participants were in their mid-30’s).The cohort consists of students from 52 middle schools across the United States in 1987 (*N* = 3,116). 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 & Kimmel, 2012).

We analyzed the longitudinal student attitudinal data toward mathematics and science from seventh grade, tenth grade and twelfth grade using latent transition analysis (LTA; Collins & Wugalter, 1992; Nylund, 2007). LTA is a longitudinal model that allows for both the identification of profiles at each time point, as well as modeling change in profiles that occurred within individuals across time. In addition, LTA profiles can be linked to auxiliary information to describe and compare trajectory profiles. We relate the trajectory profiles to demographic information about students (ethnicity, gender), student science and mathematics achievement, students’ perceived interest and support of science-related issues, and whether or not students’ attained a STEM career by their mid-30’s. Materials and methods are available as supplementary material on Science Online.

**Results and Discussion**

Four attitudinal profiles were found that varied in their affinity towards math and science. These four profiles were consistent across each grade level, though the relative size of each of the profiles differed (see legend in figure below). These attitudinal profiles were labeled as: positive, qualified positive, indifferent, and dim. These labels reflect the probability of students in each class endorsing particular items. For example, as shown in Figure 1, students in the positive class, were more likely to endorse all of the items compared to students in the qualified positive, indifferent and dim classes; while students in the dim class were less likely to endorse all of the items compared to students in the positive, qualified positive and indifferent classes. As depicted in the figure below, there was a consistent group of students who had positive attitude towards math and science that ranged in size between 18%-21% of the sample. There were student who didn’t like math or since (ranging from 27%-21% of the sample), and a class that was indifferent (between 24% and 29%). There were also students that had qualified positive attitudes—that is, they liked math but not science. These students were between 21%-27% of the sample. Though the relative size of the classes remained relatively stable, our results revealed that for some students, their attitudes towards math and since changed over time—some in a positive direction, some in a detrimental direction.

These profiles at each grade level were consistently related to mathematics and science achievement. In other words, students with more positive attitudes toward science were also students who performed higher on the science achievement measures at each grade level. Attitudinal profiles were related to gender but not ethnicity. For example, in seventh grade, 26% of all females were in the positive class compared to 35% of males. There were more females in the qualified positive class (40%) compared to males (30%) and similar percentages of males and females in the indifferent and dim class in seventh grade. This pattern of more males in the positive attitudinal profile compared to females persists through twelfth grade.

**Stability of attitudes**. The stability of the four attitudinal profiles at each grade level varied over time. Attitudes are enduring and persistent for 60% of the sample but not for the remaining 40%. 19% of all students were consistently in the positive attitudinal profile from seventh through twelfth grade; 16% were consistently in the qualified positive attitudinal profile from seventh through twelfth grade and 25% of all students were consistently in the dim or indifferent class. The other students changed their attitudinal profiles from seventh through twelfth grade. For the students who changed over time, knowing where they started in seventh grade or knowing where the ended in twelfth grade was not sufficient to describe the movement of students through the pipeline. For example, although 31% of the students were in the positive class in seventh grade and 32% were in the positive class in twelfth grade, this doesn’t describe which students were in the positive class in seventh grade and how many of them continued to be in the positive class in twelfth grade. Results indicate that 60% of the students who were in the positive class in seventh grade remained also ended up in the positive class in twelfth grade. However, the remaining 40% of the students who were in the positive class in seventh grade did not end up in the positive class in twelfth grade. Students who started off positive ended up with qualified positive (13%), indifferent (15%) and dim (12%) attitudinal profiles in twelfth grade. This pattern is consistent with the notion that student attitudes toward mathematics and science tend to decline or decrease over time. However, 10% of the students who were in the dim class in seventh grade moved to the positive class in twelfth grade which indicates that attitudes can change both in both positive and negative directions.

There is greater stability in the attitudinal profiles from tenth to twelfth grades compared to seventh to tenth grade. For example, if 82% of the students who were in the dim class in tenth grade were in the dim class in twelfth grade compared to 68% of the students who were in the dim class in seventh grade and dim class in tenth grade. This suggests that the stability of the classes depends on the years which are included with greater stability as student’s progress through high school, possibly because their identities become more solidified.

If students transitioned from one class to another from seventh to tenth grade or tenth to twelfth grade, students were not likely to move from the dim class to the positive class. Instead, they were more likely to transition from the dim class to either the indifferent class or the qualified positive class. Similarly, if students transition from the positive class, they also transitioned to the indifferent or qualified positive class rather than the dim class. The lack of stability of the four attitudinal profiles is encouraging for educators in that attitudes toward mathematics and science are not necessarily consistent and thus a malleable factor that can be influenced as students’ progress through middle and high school.

**Attitudinal profiles related to gender and ethnicity**. To better understand the characteristics of students in these different profiles we related demographic and achievement information to the different trajectories (refer to supplementary materials tables). Females were not more or less likely than males to change their attitudinal profiles over time (*b* = .14, *z*(3,009) = 1.94, *p* = .05, *Odds Ratio* = 1.15). 61% of males and 58% of females were stable in their attitudinal profiles and 39% of males and 42% of females changed their attitudinal profiles (χ2(1, *N* = 3,099) = 3.75, *p* = .05). Hispanic, African American, and Native American students (referred to as underrepresented students because these ethnicities are typically not represented in STEM fields) were not more likely to change their attitudinal profiles compared to not-underrepresented students (White and Asian, *b* = -.29, *z*(3,009) = -3.17, *p* < .01, *Odds Ratio* = .75). 64% of underrepresented students were stable in their attitudes compared to 57% of not-underrepresented students (χ2(1, *N* = 3,099) = 10.10, *p* < .001).

(see Figure X)

When comparing underrepresented females with not-underrepresented females are similar in terms of their change patterns (*b* = -.25, *z*(3,099) = -1.91, *p* = .06, *Odds Ratio* = .78). 56% of not underrepresented females are stable in their attitudinal profiles compared to 62% of underrepresented females (χ2(1, *N* = 3,099) = 3.67, *p* = .06). There are differences when comparing underrepresented males with not–underrepresented males (*b* = -.32, *z*(3,099) = -2.55, *p* < .05, *Odds Ratio* = .72). Underrepresented males are more likely to be stable in attitudinal profiles (66%) compared to not-underrepresented males (58%), χ2(1, *N* = 3,099) = 6.53, *p* < .05.

In addition to knowing which students changed their attitudes and which students did not change their attitudes, it is important to consider what changes occurred and to determine whether there are particular time points in which these changes are happening more frequently for certain groups of students compared to others. Females who did not change their attitudes, their attitudes over time were in either the indifferent or qualified positive groups (20%) or the dim group (23%). Of the females who changed attitudinal profiles, 11% started in the positive group but ended in the qualified positive or indifferent group and 11% start off in the dim group and moved to the positive or qualified positive group. Males who did not change, on the other hand, were more likely to be in the dim group (26%) or the positive group (22%) rather than the indifferent or qualified positive groups (13%). Of the males of did change, 13% started off in the positive group but ended in the qualified positive or indifferent group and 9% started in the dim group but ended in the positive or qualified positive group.

**Attitudinal trajectories related to STEM career persistence.** Students with consistent attitudes were not more or less likely to attain STEM careers (χ2(1, *N* = 3,099) = 0.03, *p* = .85). However, 37% of the students with consistently *positive* attitudes were employed in a STEM career by their mid-30’s. The importance of a consistently positive attitude toward mathematics and science and STEM career persistence is supported by other research that suggests that students need to succeed in challenging mathematics and science coursework throughout their high school years to prepare them to succeed in college (reference). If students didn’t have consistently positive attitudes, they were not as likely to persist in a STEM career. Almost 30% of the students who were not consistently positive but were classified in the positive attitudinal class in twelfth grade persisted in STEM careers. Students who were consistently low in their attitudes toward mathematics and science were not likely to persist in a STEM career (7%) but students who started with a low attitude in seventh grade but changed to a more positive attitude in twelfth grade were more likely to persist in a STEM career (29%). This suggests that although student attitudes might be more enduring or consistent for some students, it is also possible that student attitudes can change, and if they do change toward more positive attitudes, this increases the likelihood that the students will be prepared and interested in pursuing STEM careers. Even if students are not interested in science in seventh grade, it is still possible for them to change their attitudes and end up in twelfth grade with more positive attitudes toward science.

**Attitudinal trajectories related to support of science**. In addition to whether students are interested and qualified to pursue STEM careers, there is also a need to encourage all students to be interested in science-related issues. Not all students will become scientists or engineers but all students will make decisions in their daily lives that require some reasoning and participation around discussions including medical or environmental issues. 46% of the students in the consistently positive attitudinal trajectory expressed positive opinions and support of science compared to 32% in the consistently dim attitudinal trajectory and 28% in the consistently indifferent or qualified positive trajectories. While those with positive attitudes are more likely to express support of science, this percentage is low considering the inclination to encourage scientific literacy for all students regardless of whether or not they actually pursue STEM careers.

These results highlight the importance of supporting and sustaining early attitudes in mathematics and science. For particular groups of students, attitudes shifted more frequently than other groups of students. We should care about early attitudes given the long term consequences. It is also not a guarantee that an early positive attitude will sustain through high school. In fact, it is more likely that student’s attitudes toward science and math decline through high school and never improve after tenth grade (see for example, Aschbacher, Li, & Roth, 2010). These results, however, suggest that student attitudes can change but as students get older, they are less likely to change their trajectories. Students who were consistently in the positive attitude group or dim attitude group across all three years demonstrated a resistance to change. Regardless of gender or ethnicity, there were fewer students who were consistently in the indifferent or qualified positive attitudinal profiles. These students may be more susceptible to year-to-year changes compared to students in the other two attitudinal profiles. Thus, it is important to consider not just whether or not a student has a particular attitudinal profile in a single grade level but to look across multiple years to better understand where students are coming from and where they can go. Although one goal is to encourage and support more students to be qualified to pursue STEM careers another important goal is to create a more informed general public who supports scientific innovations. Supporting and sustaining early attitudes toward mathematics and science is necessary to achieve both of these goals.

Possible figures

Figure 1: single year class membership with items

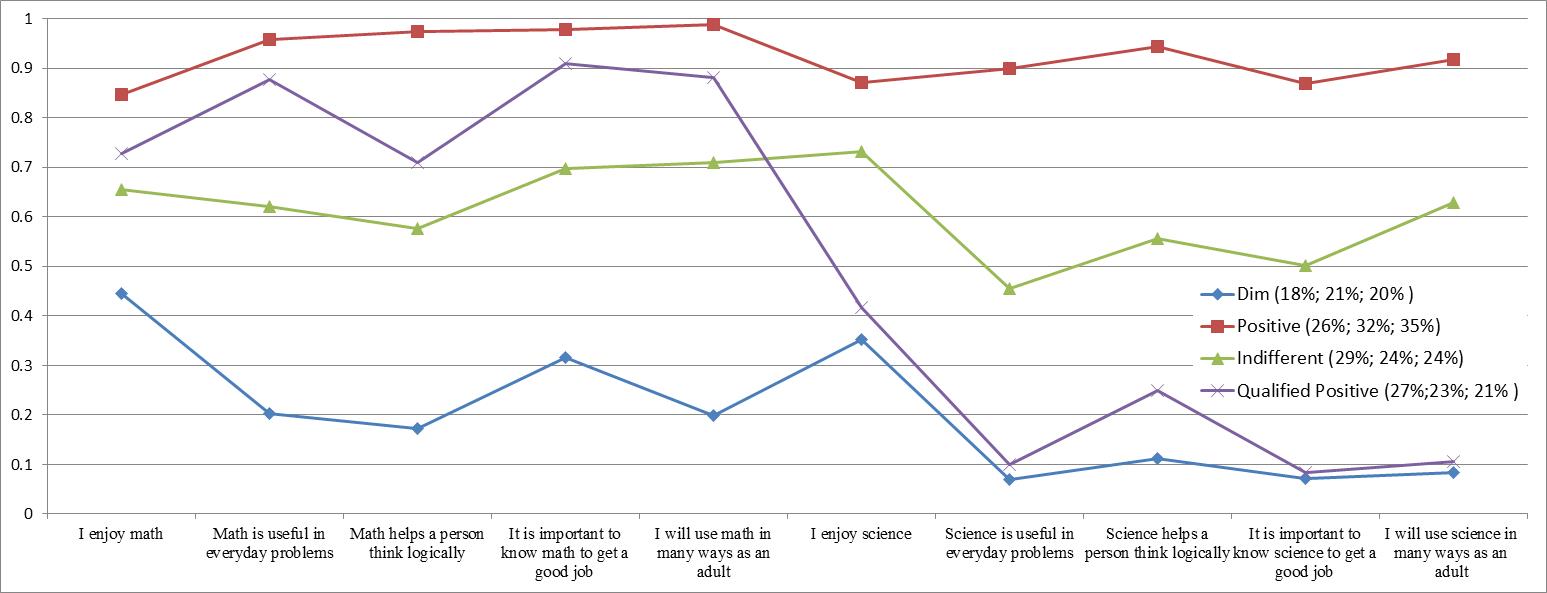


Figure 2: long term class membership (some pie chart alternatives.docx)

Figure 3: proximal outcome (achievement)

Figure 4: distal outcome (STEM career attainment)

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| Females | Males |

Possible Supplementary Materials

Descriptives for items, covariates (gender, ethnicity), distals (grade 12 mathematics achievement scores, grade 12 knowledge and support of science, STEM career attainment), etc.

LCA fit statistics for grade 7, 10, 12

LTA fit statistics

Logistic regression results for relationship to covariates

References

Ajzen, I, & Fishbein, M. (1980). Understanding attitudes and predicting social behavior. Englewood Cliffs, NJ: Prentice Hall.

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

Atwater, M. M., Wiggins, J., & Gardner, C. M. (1995). A study of urban middle school students with high and low attitudes toward science. Journal of Research in Science Teaching, 32, 665–677.

Breakwell, G. M., & Beardsell, S. (1992). Gender, parental and peer influences upon science attitudes and activities. Public Understanding of Science, 1, 183–197.

Catsambis, S. (1995). Gender, race, ethnicity and science education in the middle grades. Journal of Research on Science Teaching, 32, 243–257.

Collins, L.M. & Wugalter, S.E. (1992). Latent class models for stage-sequential dynamic latent variables. Multivariate Behavioral Research, 27, 131-157.

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, 243–271.

Ebenezer, J. V., & Zoller, U. (1993). Grade 10 students’ perceptions of and attitudes toward science teaching and school science. Journal of Research in Science Teaching, 30, 175–186.

Fadigan, K. A., & Hammrich, P. L. (2004). A longitudinal study of the educational and career trajectories of female participants of an urban informal science education program. Journal of Research in Science Teaching, 41, 835–860.

Feinstein, N.R., Allen, S., & Jenkins, E. (2013). Outside the pipeline: Reimagining science education for nonscientists. Science, 340(6130), 314-317.

Graham, M. J., Frederick, J., Byars-Winston, A., Hunter, A-B., & Handelsman, J. (2013). Increasing persistence of college students in STEM. Science, 341(6153), 1455-1456.

Hadden, R. A., & Johnstone, A. H. (1983). Secondary school pupils’ attitudes to science: the year of erosion. European Journal of Science Education, 5, 309–318.

Harvey, T. J., & Edwards, P. (1980). Children’s expectations and realisations of science. British Journal of Educational Psychology, 50, 74–76.

Havard, N. (1996). Student attitudes to studying A-level sciences. Public Understanding of Science, 5(4), 321–330.

Johnson, S. (1987). Gender differences in science: parallels in interest, experience and performance. International Journal of Science Education, 9, 467–481.

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.

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

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

National Science Board. (2012). Science and engineering indicators 2012 (NSB 12-01). Arlington, VA: National Science Foundation.

National Science Foundation. (2013). Women, minorities, and persons with disabilities in science and engineering: 2013 (NSF 13–304). Arlington, VA: National Science Foundation.

Nylund, K. (2007). [Latent transition analysis: Modeling extensions and an application to peer victimization](http://scholar.google.com/citations?view_op=view_citation&hl=en&user=cKtI1DQAAAAJ&citation_for_view=cKtI1DQAAAAJ:UeHWp8X0CEIC). Doctoral Dissertation. University of California, Los Angeles, Los Angeles.

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.

Osborne, J., Simon, S., & Collins, S. (2003). Attitudes toward 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, 1048–1073.

Simpson, R. D., & Oliver, J. S. (1985). Attitude toward science and achievement motivation profiles of male and female science students in grades six through ten. Science Education, 69, 511–526.

Smail, B., & Kelly, A. (1984). Sex differences in science and technology among 11 year old schoolchildren: II – affective. Research in Science & Technology Education, 2, 87–106.

Sundberg, M. D., Dini, M. L., & Li, E. (1994). Decreasing course content improves student comprehension of science and attitudes toward science in freshman biology. Journal of Research in Science Teaching, 31, 679–693.

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

Weinburgh, M. (1995). Gender differences in student attitudes toward science: A meta-analysis of the literature from 1970 to 1991. Journal of Research in Science Teaching, 32(4), 387-398.

Yager, R. E., & Penick, J. E. (1986). Perception of four age groups toward science classes, teachers, and the value of science. Science and Education, 70, 355–363.