

Mindsets and Math/Science Achievement

Carol S. Dweck
Stanford University
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There is a growing body of evidence that students' mindsets play a key role in their math and science achievement. Students who believe that intelligence or math and science ability is simply a fixed trait (a fixed mindset) are at a significant disadvantage compared to students who believe that their abilities can be developed (a growth mindset). Moreover, research is showing that these mindsets can play an important role in the relative underachievement of women and minorities in math and science. Below, I will present research showing that

- a) mindsets can predict math/science achievement over time;
- b) mindsets can contribute to math/science achievement discrepancies for women and minorities;
- c) interventions that change mindsets can boost achievement and reduce achievement discrepancies; and
- d) educators play a key role in shaping students' mindsets.

Mindsets

Students (and their teachers) can have different beliefs about intellectual abilities. Some believe that intellectual abilities are basically fixed—that people have different levels of ability and nothing can change that. In contrast, others believe that intellectual abilities can be cultivated and developed through application and instruction. They do not deny that people may differ in their current skill levels, but they believe that everyone can improve their underlying ability (Dweck, 1999).

Students' mindsets are measured by asking them to agree or disagree on a 6-point scale with statements such as:

You have a certain amount of intelligence, and you can't really do much to change it (fixed mindset item). No matter who you are, you can significantly change your intelligence level (growth mindset item).

Students who consistently agree with the fixed mindset items and disagree with the growth mindset ones are classified as holding a fixed mindset (about 40% of students). Those who consistently agree with the growth mindset items and disagree with the fixed mindset ones are classified as holding a growth mindset (about 40%). About 20% of students do not choose consistently and are not classified. (In some analyses, the mindset scores are used as a continuous measure and the results are similar.)

In studies that specifically examine beliefs about math or science, the questions are tailored to the domain: "You have a certain amount of math intelligence and you cannot really do much to change it." Informally, we have noted in our research that students tend to have more of a fixed view of math skills than of other intellectual skills.

Which mindset is correct? Is intelligence fixed or can it be developed? As is well known, there has been much debate on this issue through the ages. However, a considerable body of research is emerging from top cognitive psychology and cognitive neuroscience labs demonstrating that fundamental aspects of intelligence, and even intelligence itself, can be altered through training. In an extensive study with pre-schoolers, Diamond, Barnett, Thomas, and Munro (2007) showed that participants' executive control could be substantially increased through a low-cost training regime that involved giving children experience with tasks involving inhibition of responding. In a study with adults, (Jaeggi, Buschkuhl, Jonides, and Perrig, 2008) participants given training on a demanding working memory task, later scored significantly higher on an unrelated test of fluid intelligence. Fluid intelligence reflects the ability to reason and solve new problems. Moreover, the greater the training, the greater were the gains.

In addition, research studying geniuses and/or great creative contributions is yielding findings to suggest that talent alone cannot explain these phenomena. Instead the one thing that appears to set those who become geniuses or who make great creative contributions apart from their other talented peers is the deliberate practice they devote to their field (Ericsson, Charness, Feltovich, & Hoffman, 2006). In other words, genius often appears to be developed over time through focused, extended effort. As will be seen, this is precisely the kind of effort fostered by a growth mindset.

Mindsets Predict Math and Science Achievement

Blackwell, Trzesniewski, and Dweck (2007) followed 373 students across the challenging transition to 7th grade. At the beginning of the year, we assessed their mindsets, along with other motivation-relevant variables, and then monitored their math grades over the next two years. Students with fixed and growth mindsets had entered 7th grade with equal prior math achievement, for the impact of mindsets does not typically emerge until students face challenges or setbacks. By the end of the Fall term, the math grades of the two groups had jumped apart and they continued to diverge over the next two years.

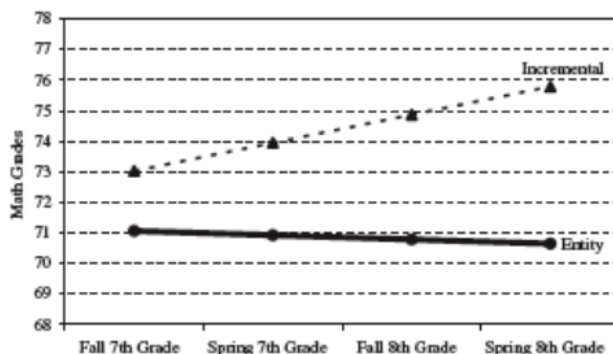


Figure 1. Graph of interaction effect of theory of intelligence and time on math achievement: Growth curves of predicted mathematics grades over 2 years of junior high school for students with incremental (+1 SD above the mean) and entity (-1 SD below the mean) theories of intelligence.

Our analyses showed that the divergence in math grades was mediated by several key variables. First, students with the growth mindset, compared to those with the fixed mindset, were significantly more oriented toward learning goals. Although they cared about their grades, they cared even more about learning. Second, students with the growth mindset showed a far stronger belief in the power of effort. They believed that effort promoted ability and that was effective regardless of your current level of ability. In contrast, those with the fixed mindset believed that effort was necessary only for those who lacked ability and was, to boot, likely to be ineffective for them. Finally, those with the growth mindset showed more mastery-oriented reactions to setbacks, being less likely than those with the fixed mindset to denigrate their ability and more likely to employ positive strategies, such as greater effort and new strategies, rather than negative strategies, such as effort withdrawal and cheating.

Thus, students' beliefs about their intelligence played a key role in how they fared in math across this challenging school transition. When students believe that their intelligence can increase they orient toward doing just that, displaying an emphasis on learning, effort, and persistence in the face of obstacles.

Grant and Dweck (2003) examined college students' achievement as they coped with one of the most challenging and important courses in their curriculum: pre-med organic chemistry, the gateway to the pre-med curriculum. In this study, to address issues in the achievement motivation literature, we focused on students' goals—how much they were oriented toward learning goals vs. how much they were concerned with validating their intelligence through their schoolwork. Research has shown that these orientations are closely aligned with mindsets. Students with the growth mindset tend to orient more toward learning goals and students with the fixed mindset tend to orient more toward validating their intelligence (Blackwell, et al., 2007; Hong, Chiu, Dweck, Lin, & Wan, 1999; see also Leggett & Dweck, 1988). I will use continue to use the mindset terminology here for simplicity.

In this study, Grant and Dweck found, first, that a growth orientation, compared to a fixed ability orientation, predicted higher final grades in the organic chemistry course, controlling for math SAT scores as an index of entering ability. This grade advantage was caused by the growth-oriented students' use of deeper learning strategies. Moreover, we found that a fixed mindset predicted students' failure to recover from an initial poor grade, whereas a growth mindset predicted successful recovery. Finally, when we looked further into the data, we found that among students who held a fixed mindset, males outperformed females in final grades; however, among students who held a growth mindset, females slightly (though not significantly) outperformed males.

It should be noted that in these studies and in many of the studies discussed below, students who have a fixed mindset but who are well prepared and do not encounter difficulty can do just fine. However, when they encounter challenges or obstacles they may then be at a disadvantage.

Disparities in Math/Science Achievement

There is increasing evidence that mindsets can play a key role in the underachievement of women and minorities in math and science, as well as their lesser tendency to elect to pursue careers in math and science.

In two recent experiments, reported in *Science* (Dar-Nimrod & Heine, 2007), college females, before taking a challenging math task, were given one of two explanations of the gender difference in math achievement. One group was told that the gender difference was genetically based (a fixed mindset manipulation), whereas the other group was told that the gender difference originated in the different experiences that males and females have had (more of a growth mindset manipulation). In both experiments, females given the fixed mindset explanation performed significantly worse than those given the growth mindset explanation.

Recently, Good, Rattan, and Dweck (2007a) followed several hundred females at an elite university through their calculus course to understand how mindsets influenced their sense that they belonged in math, their desire to pursue math courses in the future, and their grades in math. We found that females' mindsets (and the mindsets they perceived others in their class to hold) were an important factor. Females who held a growth mindset were less susceptible to the negative effects of stereotypes. Even when they reported that negative stereotypes about women and math were widespread in their math environment, they continued to feel that they belonged in math, they intended to pursue math courses in the future, and they continued to earn high grades. However, when women held a fixed mindset, negative stereotypes affected them more. Those who reported that negative stereotypes were widespread in their math environment showed an eroding sense that they belonged in math over the course of the semester, and when this happened it was accompanied by a decreased intention to take math in the future and a decrease in their final grades in the course.

Women's representation in math and science is far lower than their past grades and achievement test scores would warrant. An eroding sense of belonging may be a key factor in women's decision to go elsewhere. Our research shows that a fixed mindset contributes to this eroding sense of belonging, whereas a growth mindset protects women's belief that they are full and accepted members of the math community.

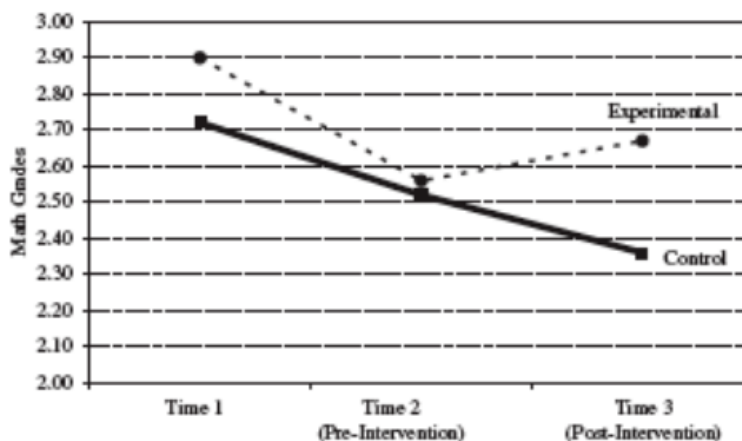
Aronson (2007), in two as yet unpublished studies, has demonstrated that mindsets can play a large role in minority students' underperformance on standardized tests. In these studies, Aronson administered the verbal portion of the medical boards (the MCAT) to Black and Latino students who wished to go to medical school. The students were given one of two instructions. Half received fixed mindset instructions, in which they were told that the test measured a stable underlying ability. The other half were told that the test measured a set of skills that could be improved with practice. The performance of the two groups was highly discrepant, with those who received the growth mindset instructions getting significantly more items correct.

Negative stereotypes about ability are fixed mindset beliefs. They embody the belief

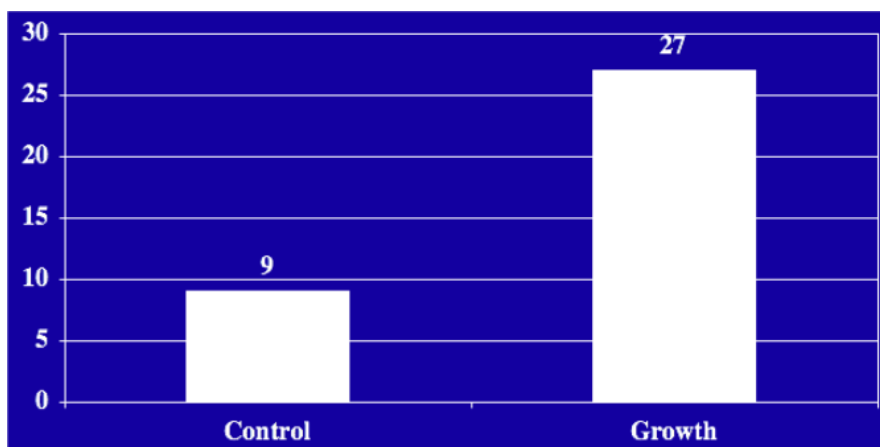
that an ability is fixed and that certain groups do not have it. The more that members of a negatively stereotyped group already hold a fixed mindset, the more susceptible they may be to such a message. The more they hold a growth mindset, the more they may be able to withstand negative messages about their ability.

Interventions That Change Mindsets

Two studies (Blackwell, et al., 2007, Study 2, and Good, Aronson, & Inzlicht, 2003) created workshops that taught 7th graders a growth mindset. In both studies, students were taught that the brain is like a muscle that grows stronger with use, and that every time they stretched themselves and learned something new their brain formed new connections. They were also shown how to apply this lesson to their schoolwork. In addition, in both studies, students in the control groups received noteworthy information in comparable workshops. For example, in the Blackwell, et al. study, the control group received 8 sessions of useful study skills. Nonetheless, Blackwell et al. showed, the control groups' grades in math continued to decline, whereas the grades of the students taught the growth mindset showed a clear rebound.

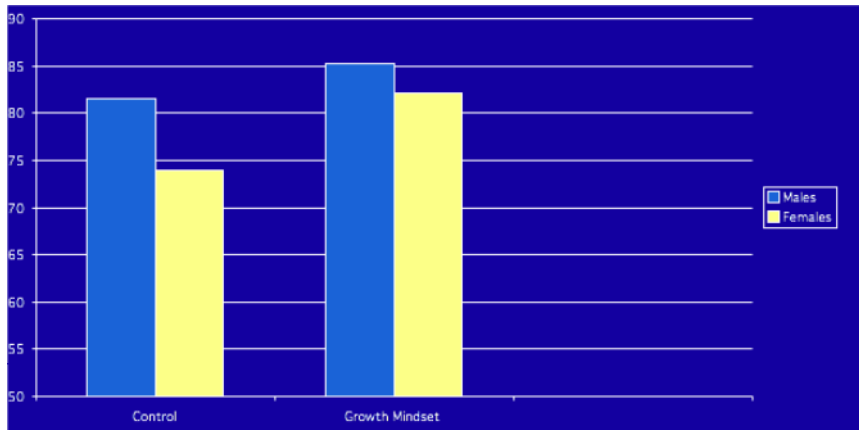


In addition, teachers (blind to whether students were in the control group or the growth mindset (experimental) group, singled out three times as many students in the experimental group as showing marked changes in their motivation (27% in the experimental group vs. 9% in the control group).



In the Good et al. study, the students in the growth mindset group, compared to those in the control group, showed significantly higher scores on their next math achievement test. In addition, although both girls and boys in the growth mindset group showed clear gains compared to the girls and boys in the control group, the girls showed even greater gains than the boys and thus decreased the achievement gap.

Math Achievement Test Scores Following Growth Mindset Workshop Vs. Control Workshop



Although both of the above studies were conducted with largely minority students in New York (Blackwell, et al., 2007) and Texas (Good, et al., 2003), the same kinds of results have been obtained with students at an elite university. Aronson, Fried, and Good (2002) taught students at Stanford University a growth mindset by means of a workshop. To shore up their understanding of the growth mindset, the students also tutored younger students within a growth mindset framework. There were two control groups. One received a comparable workshop and tutoring experience but organized around the idea that there are many different kinds of intelligence and that one should not be discouraged if one does poorly in a given area. The other control group received no treatment. At the end of the semester, the students—both Black and White students—in the growth mindset workshop had earned significantly higher grade point averages than those in the control groups (the control groups did not differ from each other). Although the Black and White students in the growth mindset group showed similar advantages over the control group in terms of grade point average, the Black students showed even larger increases than did the White students in their enjoyment of academic work and in their valuing of school.

The research reviewed in this section has demonstrated that changing students' mindsets can have a substantial impact on their grades and achievement test score. In each case, the impact of the growth mindset workshops endured long enough to boost end-of-term measures of achievement. It will be important to follow students over longer periods of time to see whether the gains last, but it is likely that environmental support is necessary for them to do so. For example, it would be important to have teachers who subscribe to a growth mindset, present material in that framework, are tuned into students' learning styles and needs, and give feedback to students in ways that sustain

their growth mindset. Therefore, it will be extremely important to study ways in which the educational environment can teach and support a growth mindset over time.

The Role of Parents and Educators

For the last few decades many parents and educators have been more interested in making students feel good about themselves in math and science than in helping them achieve. Sometimes this may take the form of praising their intelligence or talent and sometimes this may take the form of relieving them of the responsibility of doing well, for example, by telling them they are not a “math person.” Both of these strategies can promote a fixed mindset.

Our research (Cimpian, Arce, Markman, & Dweck, 2007; Kamins & Dweck, 1999; Mueller & Dweck, 1998) has shown that giving students praise for their intelligence, as opposed to praise for process (such as effort or strategy) makes students think that their abilities are fixed, makes them avoid challenging tasks (so they can keep on looking intelligent), makes them lose confidence and motivation when the task becomes hard, impairs their performance on and after difficult problems, and leads them to lie about their scores afterwards. Process praise (such as praise for effort or strategy), in contrast, leads students to seek and thrive on challenges.

In a recent study, Good, Rattan, & Dweck (2007b) asked adult participants to act as teachers and to give feedback to 7th grade students who had received a grade of 65% on an exam. Beforehand, half of the teachers had learned from a “scientific article” that math intelligence is fixed and half had learned that math intelligence is acquirable. Teachers who were given a growth mindset in math were then found to give more encouragement and support to the student (e.g., tell her that she could improve if she worked hard) and to give more concrete strategies to the student for improvement (e.g., tell him that he needs to change his study strategies; suggest that she work with a tutor after school; provide her with challenging math tasks). In contrast, those given a fixed mindset were more likely to simply comfort the student, for example by explaining that not everyone has math talent-some people are “math people” and some people aren’t or by consoling her for her grade by telling her that not everyone can be smart in math. In addition, learning that math is a fixed trait led teachers to favor boys, giving them significantly more concrete suggestions for improvement than they did when they gave feedback to a female student.

In other studies, we are showing that when math greats are presented to students as born geniuses, it puts students into a fixed mindset; whereas when math geniuses are presented as people who loved and devoted themselves to math, it conveys a growth mindset to students (Good, Rattan, & Dweck, 2007c).

These and other studies are demonstrating how adults’ feedback practices and adults’ own mindsets can influence students to think about their math (or science) ability in different ways. It is also interesting to note that in cultures or subcultures that are producing a large number of mathematics and science graduates, and espe-

cially a substantial number of female mathematics and science graduates (such as East and South Asian cultures), fewer assumptions are made about inherent ability (vs. effort) as the basis of success. As one example, Stevenson and Stigler (1992) found that parents and teachers in Japanese culture, relative to those in the U.S., consistently place far greater emphasis effort as opposed to inherent ability as the cause of achievement. And indeed, recent data collected by UNESCO, OECD, and EUROSTAT (reflecting university graduates by fields of study for the year 2004) show Japan to have the highest percentage of female university graduates in mathematics and computer science of the 30 countries studied. (India and China were not included in their sample but would be expected to show similar patterns.)

Recommendations

1) Ways in which educators can convey a growth mindset to students:

a) By teaching students about the new science of brain plasticity and the new view of talent and giftedness as dynamic attributes that can be developed.

Too often, the brain is believed to be static, and talent and giftedness are seen as permanent, unchanging personal attributes that automatically bring later success. Thus, when educators introduce a subject area, it is important for them to emphasize that skills in this area are acquired through instruction and personal application. This is not to deny that students may learn at different rates, but it is meant to emphasize that these skills are not the domain of a special few.

As part of regular classroom teaching or in school-sponsored growth mindset workshops (such as those described in Dweck, 2007; see also Aronson et al., 2002; Blackwell et al., 2007; Good et al., 2003), students can be taught that the brain is like a muscle that gets stronger and works better the more it is exercised. They can also be taught that every time they stretch themselves, work hard, and learn something new, their brain forms new connections and that, over time, they become smarter. In these workshops, they are also taught how to apply this message to their schoolwork.

Below are some screenshots from the *Brainology* workshop that we have developed. It is a 6-module interactive computer-based workshop that teaches students about the brain, teaches them the growth mindset, and teaches them ways to make their brains work better to enhance the formation of new connections. (Uri Treisman and Linda Chaput have also been developing computer-based growth mindset interventions that can precede a new unit of study or that can stand alone.)

Navigating Brainology



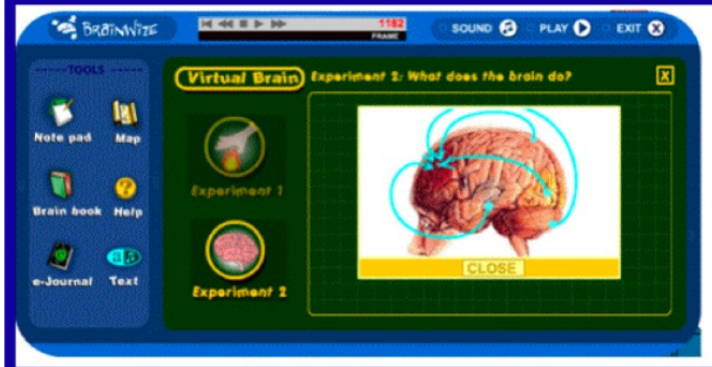
Brain Orb as Guide



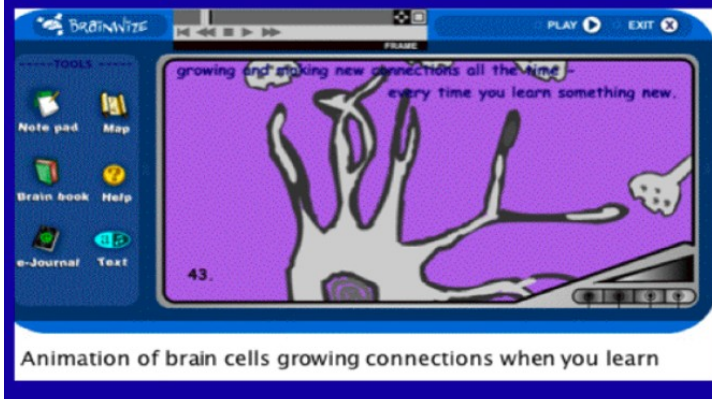
Visit to Brain Lab



Brain Experiments



The Learning Brain



The image of new connections forming proved extremely motivating to the students in our pilot studies. They reported that as they paid attention in class or studied difficult material, they pictured their neurons growing new connections; and that when they considered not studying, they warned themselves that they would be missing a chance to form new connections. Teachers also reported students' renewed interest in learning as a means of promoting new connections.

Students can also be taught about the research on people who make great, creative contributions (Ericsson, et al., 2006). Too often in our culture these geniuses are portrayed as having simply been born with special talents. Students should know that the distinguishing feature of such people is their passion and dedication to their craft, and particularly, the way in which they identify, confront, and take pains to remedy their weaknesses. Thus, students must learn that passion, dedication, and self-improvement—and not simply innate talent—are the road to genius and contribution. As we have shown in our research (Good, Rattan, & Dweck, 2008), this message may be especially helpful for females, who may not believe that they fit the image of the

born genius in math and science.

When the math and science greats are (accurately) presented as people who loved and were dedicated to their craft, anyone who loves math or science can be a welcome and full-fledged member of the math-science community. However, when the greats are presented as born geniuses, then only those who believe they, too, were born geniuses feel like full-fledged members of the community and can hope to make noteworthy contributions.

Children's T.V. programs, educational spots, children's books, and children's computer programs and computer games can all be used to send these messages: that the brain grows new connections every time we face challenges and learn, and that great mathematicians and scientists are people who have engaged in this process more than other people.

We have noted that teaching a growth mindset changes student-to-student discourse in the classroom, and this would be interesting to portray in children's programs and teaching materials. In a fixed mindset, school may often be perceived by students as a place where they are tested and judged—and, understandably, they are often resistant to this. However, in a growth mindset, school may more often be perceived as a place in which you can grow your brain. In our growth-mindset Brainology intervention, teachers reported that students had begun talking to each other about their learning strategies and their attempts to grow new connections. Thus, another channel for promoting a growth mindset could be depicting peers as interacting in terms of their desire to form neural connections and their motivation to make their brains smarter.

b) Through the portrayal of challenges, effort, and mistakes as highly valued.

Throughout our research, we have seen that students with a fixed mindset are threatened by challenges, effort, and mistakes, for these are the things that threaten to reveal the limits of the students' ability. In our schools and in our society, we too often portray effortless achievement as the sign of true talent. Many bright students, praised for their easy successes, may come to believe that they are gifted only when things come easily to them (Hong, et al., 1999; Blackwell, et al., 2007). Thus they may shy away from challenges, limit their effort, and try to avoid or hide mistakes.

It is therefore important for educators, parents, and society to communicate that we value and admire challenge-seeking, hard work, and learning from mistakes—and that we do not value easy, low-effort successes. How can we expect students to embrace the challenging advanced study and the challenging careers that scientists must face if we have taught them that talent is about easy success?

Indeed, students at all skill levels and grade levels must be challenged and must be taught to enjoy challenges, effort, and mistakes. Below are some examples of things educators or parents could say to send these messages:

“Let's do something hard that we can learn from, not something easy and boring.”

“Boy, this is hard. This is what I call fun.”

“Let’s go around and have each of you share something hard you learned today that you didn’t know before.”

“Who had a good struggle? Let’s share what we struggled with today”

“Get ready for a terrific struggle! Are you ready? Here we go.”

“That was a lot of hard work. Can you just imagine all the connections you grew today?”

“Who thinks they made a really interesting mistake?”

“Who else made a terrific mistake that will help us learn?”

My research has taught me that students are tremendously sensitive to what we adults value in them. They quickly pick up the cues about what we admire, and act accordingly. Thus instead of trying to puff up their confidence in false ways, by giving them easy tasks that they can dispatch without effort or mistakes, we can teach them the very values that are at the heart of scientific and mathematical contributions: Love of challenge, love of hard work, and the ability to embrace and learn from our inevitable mistakes.

These messages can be readily woven into teaching materials, children’s programs, children’s books, and computer games.

c) Through **process praise and feedback**.

Process praise/feedback includes feedback about strategies, effort, perseverance, challenge-seeking, improvement, etc., as opposed to *person* praise/feedback, which refers to the intelligence or talents of the student, or *outcome* praise/feedback, which puts the focus on the final product (Cimpian, et al., 2007; Kamins & Dweck, 1999; Mueller & Dweck, 1998). Below are examples of process praise/feedback:

“I like the way you tried all kinds of strategies on that math problem until you finally got it. You thought of a lot of different ways to do it and found the one that worked!”

“I like that you took on that challenging project for your science class. It will take a lot of work—doing the research, designing the apparatus, buying the parts, and building it. Boy, you’re going to learn a lot of great things.”

It is very important to give process feedback to the most able students, who as suggested above, have often coasted along, gotten good grades, and been praised for their intelligence. These may be the very students who opt out when the work becomes more difficult. They may not know how to exert effort or they may not want to start exerting effort, since it threatens their sense of their giftedness. Thus it is essen-

tial for educators to put the emphasis on *process* for students who are used to relying on their talent or gift:

“That was too easy for you—sorry I wasted your time. Let’s find something you can learn from.” Here, rather than perpetuating the praise for intelligence, the feedback re-orientes the student toward learning.

“I know school used to be easy for you and you used to feel like the smart kid all the time. But the truth is that you weren’t using your brain to the fullest. I’m really excited about how you’re stretching yourself now and working to learn hard things.”

Sometimes students work hard and *don’t* do well? What can educators or parents do then?

“I liked the effort you put in, but let’s work together some more and figure out what it is you don’t understand.”

“We all have different learning curves. It may take more time for you to catch on to this and be comfortable with this material, but you if you keep at it like this you will.”

“Everyone learns in a different way. Let’s keep trying to find the way that works for you.”

2) Ways that educators can be taught a growth mindset and how to communicate it to their students.

It is interesting to note that educators with both fixed and growth mindsets create self-fulfilling prophecies. Research has shown that when teachers believe in fixed intelligence, the students they identify as having high ability are the only ones who tend to achieve well in their classes. When teachers hold a growth mindset, a much broader range of students do well (Rheinberg, 2000). Thus for educators with a fixed mindset, training must counteract the years of evidence that confirms their fixed mindset.

Teacher-training curricula in schools of education, continuing education programs for existing teachers, and training for young teachers participating in such programs as Teach for America need to include a) the latest findings in brain plasticity and their implications for all children’s potential to learn, b) the findings that dedication and self-improvement - and not just existing talent - bring students long-term success, c) the finding that process praise promotes more lasting confidence and motivation than intelligence praise or outcome praise, and d) information on the need for students at all levels to be challenged appropriately.

It may be particularly important to present the growth mindset information in a non-threatening way to teachers whose curricula and teaching methods have been guided by a fixed mindset. This could be done by acknowledging that the idea of a fixed brain was more or less the standard view until recent findings in neuroscience

and cognitive psychology revealed the great plasticity of the brain and the fact that basic aspects of intelligence can be taught.

Aside from teacher training curricula, this information could be woven into curricular material that teachers receive, showing them, for example, how to introduce new units and how to give feedback to students so as to promote a growth mindset. In addition, publications that are read by educators can regularly include information on the growth mindset, how to communicate it to students, and, in that context, how best to promote learning in all students.

3) Ways to convey to females and minority students that past underachievement has its roots in environmental rather than genetic factors and can be overcome by enhanced support from their educational environment and by personal commitment to learning.

Research shows that when females and minorities are informed that they can do as well as others in a subject area—and particularly when this information is placed in a growth mindset framework—achievement gaps are decreased (Dar-Nimrod and Heine, 2007; Good, Rattan, & Dweck, 2008; Aronson & Steele, 2005). It is therefore important for teachers and for educational material to send this message to females and minorities all grade levels, since even students who are interested in math and science at the college or graduate school level are often deterred from pursuing math and science—either because of their own fixed mindset or because they perceive that others in the field regard them through a fixed-mindset lens as inherently less capable. Although a fair amount of research has spoken to this issue, most of the studies have been relatively small-scale. It might thus be interesting to have a larger scale study that looks at the efficacy of such interventions on the math-science achievement (and interest) of females and minority group members.

4) Ways to incorporate the growth-mindset message into high stakes tests and into the teaching lessons that surround them.

It is important, particularly if this era of high stakes testing continues, for students to understand that these tests assess current skills and not long-term potential to learn. This is critical since many students make take their disappointing achievement test scores as a measure of their fixed, underlying ability and become discouraged about their academic futures.

It is also critical for the students who do well on these tests not to begin to believe that acing standardized tests is the route to long-term success in math and science.

It would be very interesting to perform a larger-scale study along the lines of the study performed by Joshua Aronson with Black and Latino students who took the verbal portion of the MCAT. The College Board has expressed interest to me in varying the instructions on their exams to be more in line with a growth mindset (incorporating in the instructions the idea that the test measures specific skills that can be improved with practice). A controlled study could potentially be carried out in which some stu-

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