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Even Einstein Struggled: Effects of Learning About Great Scientists' Struggles on High School Students' Motivation to Learn Science

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Students' beliefs that success in science depends on exceptional talent negatively impact their motivation to learn. For example, such beliefs have been shown to be a major factor steering students away from taking science and math courses in high school and college. In the present study, we tested a novel story-based instruction that models how scientists achieve through failures and struggles. We designed this instruction to challenge this belief, thereby improving science learning in classroom settings. A demographically diverse group of 402 9th and 10th grade students read 1 of 3 types of stories about eminent scientists that described how the scientists (a) struggled intellectually (e.g., made mistakes in investigating scientific problems, and overcame the mistakes through effort), (b) struggled in their personal life (e.g., suffered family poverty and lack of parental support but overcame it), or (c) made great discoveries (a control condition, similar to the instructional material that appears in many science textbooks, that did not describe any struggles). Results showed that participation in either of the struggle story conditions improved science learning postintervention, relative to that of students in the control condition. Additionally, the effect of our intervention was more pronounced for low-performing students. Moreover, far more students in either of the struggle story conditions felt connected to the stories and scientists than did students in the control condition. The use of struggle stories provides a promising and implementable instructional approach that can improve student motivation and academic performance in science and perhaps other subjects as well.

Keywords: beliefs in exceptional scientific talents, scientists struggle story intervention, improving motivation in science learning

We recently asked a set of 9th and 10th graders what kind of people can be scientists. The interviews were conducted in schools currently implementing a program designed to teach students about the value of effort and persistence for learning science. Almost all of the students responded in ways that would garner approval from teachers and researchers: "A scientist can be any person who has a spark of curiosity in himself or herself," "Anyone who seems interested in the field of science," and "People who can work hard." These egalitarian responses, however, did not seem to translate into students' views of themselves. For example, when asked whether they could become scientists, many students had trouble imagining their roles in that field, admitting, "Well, if I'm being honest, science is a field I have not thought much about because I am not good in it," and "I won't, because I don't get the best grades in science class right now. Even if I work hard, I will not do well." Our interviews suggest that even if students parrot the belief that everyone has the potential to be successful in science, these beliefs may not translate into beliefs about their own abilities in science.

We view this disconnect between students' general comments about scientists and their comments about themselves as problematic. A serious drawback of the belief in exceptional scientific

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talents is students who believe that high-level scientific performance requires exceptional inborn ability tend to give up before they give themselves a chance to develop their own talents (Bandura, 1977a, 1986; Dweck, 2000; H. Hong & Lin-Siegler, 2012; Murphy & Dweck, 2010; Pintrich, 2003). These beliefs are likely to undermine effort when it is most needed; when students struggle in science classes, they may misperceive their struggle as an indication that they are not good at science and will never succeed in it (Dweck, 2010, 2012; H. Hong & Lin-Siegler, 2012). The belief in the necessity of exceptional scientific talent for science learning hinders efforts to increase the number of students pursuing science, technology, engineering, and mathematics (STEM) careers (National Academy of Science, 2005).

The purpose of the current study was to confront students' beliefs that scientific achievement reflects ability rather than effort by exposing students to stories of how accomplished scientists (Albert Einstein, Marie Curie, and Michael Faraday) struggled and overcame the challenges in their scientific endeavors. These stories were designed to show students that even the most accomplished scientists are relatable people who often fail and struggle through difficulty prior to their triumphs. To test the impact of hearing such stories, we conducted a randomized field experiment in which students read biographical stories about eminent scientists' struggles to achieve, struggles to overcome personal difficulties, or control stories recounting the scientists' achievement. The goal was to test whether hearing such stories would improve students' motivation and academic performance in science classes.

Theoretical Framework

Motivation has been a topic of interest for educational psychologists since the early 1930s. Researchers have defined motivation in many different ways but generally agree that the core of motivation describes why a person selects one action over another with great energization or frequency (Bargh, Gollwitzer, & Oettingen, 2010; Gollwitzer & Oettingen, 2012; McClelland, 1978; Touré-Tillery & Fishbach, 2014). For instance, a motivated student often persists in the face of challenging problems, intensely focuses on the task at hand, and often concerns oneself about ways to make things better without becoming distracted by other activities.

Motivation is essential for successful learning and performance, but crucially related to motivation is how one attributes successes and failures. For simplicity, the discussions of the theoretical rationale behind our study will focus primarily on two areas: (a) attribution theories, or beliefs about the causes of one's own and other people's outcomes and behaviors; and (b) instructional methods to effectively convey the message to students in schools that success comes by effort.

Self-Attributions and Their Effect on Motivation

The way an individual selects one action over another is directly related to one's confidence in being able to attain a successful outcome. If people believe that they will be unsuccessful in obtaining a certain outcome, they are less likely to engage in actions in pursuit of that outcome, and if they do, it is unlikely that the person will persist and invest 100% effort (Dweck & Leggett, 1988; Oyserman, Bybee, & Terry, 2006). The basic premise of attribution theory is that people's judgments of the causes of their own and other people's success or failure have important motivational effects (Bandura, 1986, 2005; Renninger, Bachrach, & Posey, 2008; Weiner, 1986, 1992, 2000). That is, people who credit their failures to insufficient effort will be more likely to undertake difficult tasks and persist in the face of failure. This is because they see that outcomes can be influenced by how much effort they invest. In contrast, those who ascribe their failures or deficiencies in learning and performance to uncontrollable factors such as innate intelligence (e.g., "Einstein was lucky because he was born smart") will display low achievement strivings and give up readily when they encounter obstacles (Dweck, 2006; H. Hong & Lin-Siegler, 2012). Clearly, people decrease their motivation to learn when they feel that, regardless of what they do, very little change can happen.

Multiple sources influence people's attribution about their own and others' success and failure. The source we are particularly interested in for the present study is people's implicit beliefs about ability and effort, which Dweck and colleagues (Blackwell, Trzesniewski, & Dweck, 2007) refer to as "mind-set." There are usually two types of mind-sets that have been shown to have a striking impact on people's motivation and achievement, namely, fixed and growth mind-sets (Dweck, 2006). When setbacks occur, people with fixed mind-sets perceive themselves as unalterably incompetent at the task; as a result, they avoid challenging tasks and are reluctant to invest effort (Dweck & Leggett, 1988). These people also tend to adopt performance goals, in which people are more interested in positive judgment of their competence and avoid challenging problems that might lead to failure (Dweck & Leggett, 1988). In contrast, people with growth mind-sets perceive ability and learning outcomes as attributes that can be changed through increased effort (Dweck, 2009, 2010, 2012, which positively influences their motivation to learn (Bandura, 1977b, 1986; Dweck & Leggett, 1988; Greeno, 2006; Grube, Mayton, & Ball-Rokeach, 1994; Hammer, 2007; Mischel, 2004; Walton, Paunesku, & Dweck, 2012). These people tend to adopt mastery goals, in which they try to understand what they are doing and master difficult tasks to increase their competence (Dweck & Leggett, 1988). The aim of our study is to help students reverse the perception that exceptional talent is required for success in science and recognize that they can succeed if they invest sufficient effort.

These different beliefs, or mind-sets, create different psychological orientations in which students can either cherish challenges and be persistent in the face of setbacks or avoid challenges and be devastated by these setbacks. To examine the effect of mind-set on school performance, Blackwell and colleagues (2007) followed several hundred students in New York City during their difficult transition to junior high school. Although all students' grades were similar at the beginning of the study, a large gap in their school performance emerged in the first term and continued to diverge over the next 2 years. Apparently, students with growth mind-set (those who believed that they can develop their own intelligence) outperformed their peers with fixed mind-set (those who believed that they cannot change the level of their own intelligence).

These global beliefs about effort and ability affect not only overall performance in schools but also specific domains, namely, math and science-related subjects (Dweck & Master, 2009). For example, many students believe that math and science ability is innate, but writing ability can be improved with practice (Dweck & Master, 2009). As children enter adolescence and begin to engage in higher level science and math learning, the tendency to believe that exceptional talents are required to succeed in these areas increases (Rattan, Savani, Naidu, & Dweck, 2012; Stipek & Gralinski, 1996). Compared with elementary schoolchildren, middle school and high school students tend to view science and math as difficult subjects that require special ability and talents relative to other subjects (Eccles-Parsons et al., 1983). Difficulty in learning science may encourage the belief that exceptional talents are required when effort does not immediately pay off (e.g., Licht & Dweck, 1984).

Beliefs About Exceptional Talents Can Negatively Impact Science Learning

Belief in the necessity of exceptional scientific talents has been shown to be one of the major factors steering students away from science and math courses in both high school and college (Blickenstaff, 2005; Singh, Granville, & Dika, 2002; Wang, 2013). Media, trade books, and school textbooks contribute to students' stereotypical images of science and scientists. Scientists are often portrayed as unusually smart, White males who solve problems without much effort or help from others (Chambers, 1983; Farland, 2006; Finson, 2002; Schibeci & Sorensen, 1983). For example, a children's book called *Great Scientists in Action* (Shevick, 2004) highly emphasized what the scientists did "right" to achieve, but none of the stories emphasized what they did "wrong" to also become successful. These images negatively affect students' beliefs and attitudes toward science (Barman, 1997; Chambers, 1983; Farland, 2006; H. Hong & Lin-Siegler, 2012; Mead & Métraux, 1957).

Students with the belief that success in science requires exceptional talent often avoid science classes, give up easily when they experience setbacks in their experiments, and often feel threatened by students who thrive in science classes (Shumow & Schmidt, 2014). Despite the high percentage of students who initially express interest in STEM subjects when enrolling in college, only 15% to 25% of these students actually graduate with degrees in STEM areas (Safdar, 2013). High drop-out rates in STEM majors appear to reflect that students who major in these fields interpret their struggles in math and science classes as being indicative of a lack of talent in these areas (Safdar, 2013; R. Stinebrickner & Stinebrickner, 2008; T. R. Stinebrickner & Stinebrickner, 2011, 2013).

The good news is that beliefs about science and scientists are often malleable, and a growth mind-set can be directly taught to students (Dweck, 2008; Dweck & London, 2004). For example, a growth mind-set can be fostered by providing students with scientific articles or films about the malleability of intelligence (Y. Y. Hong, Chiu, Dweck, Lin, & Wan, 1999; Niiya, Crocker, & Bartmess, 2004) or with physiological evidence for how the brain is like a muscle and can be developed with effort (Aronson, Fried, & Good, 2002; Blackwell et al., 2007; Good, Aronson, & Inzlicht, 2003).

As shown and discussed in the previous paragraph teaching students the importance of effort (vs. ability) in order to increase performance and self-confidence is especially essential for science learning. The experimental nature of science depends on people's ability to persist in the face of obstacles and to use failures to discover new things. But still, what is less known is which *aspect* of effort needs to be taught to indeed promote productive work ethic and success in schools. The present study was intended to contribute to this body of research by highlighting the necessity of going through failures and struggles in order to succeed, especially in science learning. To achieve this goal, we developed an innovative approach to convey a growth mind-set message through highly respected role models' struggles (life and intellectual). We compared this approach with presenting stories about scientists' achievements, which exemplify a fixed mind-set. We then examined how these instructional approaches affect students' motivation and performance in science classes.

Story-Based Instruction

Implementing story-based instruction to convey the message that struggle is a necessary part of success in school settings presents us a set of unique challenges because of a variety of distracting factors. For instance, students can choose to ignore classroom instruction and instead watch other peers acting up or look out the window at passing traffic. Besides these external distractions, students' internal values and beliefs can also interact with the instruction counterproductively. As such, classroom instruction, whether content-focused or motivation-focused, always competes for students' attention along with other sources of distractions (Billington & DiTommaso, 2003).

Why are we using the age-old art of storytelling to confront students' beliefs about science learning? One reason is that stories can powerfully impact people's attitudes, beliefs, and behaviors (Kaufman & Libby, 2012; Oatley, 1999). For instance, stories are "self-involving" and shape readers perspectives and emotions (Miall & Kuiken, 1998). The most impactful stories are usually detailed, honest, personal, and involve struggles: "When you want to motivate, persuade, or be remembered, start with a story of human struggle and eventual triumph" (Zak, 2014). Such stories are memorable because people become emotionally involved in the lives of the characters, see the world as they do, or imagine situations that may be similar to theirs. Second, stories often describe actions that a character takes to complete a goal (Black & Bower, 1980). People tend to recall action processes that are involved in the pursuit of a goal better than descriptions of what characters look like (Black & Bower, 1980).

A number of science educators have suggested that scientists' personal narratives, anecdotes, or life stories are valuable resources that can be used to inspire students' science learning (Eshach, 2009; H. Hong & Lin-Siegler, 2012; Lin & Bransford, 2010; Martin & Brouwer, 1993; McKinney & Michalovic, 2004; Solomon, 2007). Embedded in these narratives are usually scientists' role models who provide templates of the actions or behaviors that are needed to achieve specific goals. Narratives also convey the message that the road to scientific discovery involves failed attempts and mistakes. Highlighting this process not only enhances recall and understanding of the information embedded in the story (Black & Bower, 1980) but also portrays scientists as relatable role models to connect students emotionally. For instance, bringing in the backstory of a successful scientist may help students realize that their own struggles are common in science but, more importantly, possible to overcome (H. Hong & Lin-Siegler, 2012).

Scientists' struggle stories also focus on the scientific process, rather than the final product, which can also lead students to revise their existing perceptions and beliefs about scientists (H. Hong & Lin-Siegler, 2012). H. Hong and Lin-Siegler (2012) demonstrated the benefits of exposing 10th grade Taiwanese physics students to stories about successful scientists' struggles. Students were randomly assigned to one of three conditions: (a) the struggle story condition, describing the personal and intellectual struggles of Galileo, Newton, and Einstein; (b) the achievements condition, emphasizing the achievements of these scientists; or (c) the control condition, providing more content instruction in physics that the students were studying in school.

Students in the struggle story condition perceived scientists as individuals, like themselves, who needed to overcome obstacles to succeed. In contrast, students in the achievement story condition expressed views that scientists are innately talented individuals who are endowed with a special aptitude for science. Learning about scientists' struggles not only sparked interest among students who initially displayed little interest for science but also improved students' retention of theoretical material and performance in solving more complex tasks based on the lesson material. Teaching more content knowledge, however, did not result in increased motivation, nor did it improve complex physics problem solving. These findings provided us with strong empirical evidence that students' beliefs in exceptional scientific talents can be confronted by learning about how scientists struggled in order to succeed.

As demonstrated in previous research, a key element in the struggle stories is that they bring to the forefront the model of a struggling scientist. The present study investigated how different types of story-based instruction of struggling scientists affect students' motivation and learning in science classes. In the following section, we discuss the ways in which role models can impact beliefs and performance.

Role Models in Story-Based Instruction

Role models provide examples of success in a given area one wishes to emulate and achieve (Asgari, Dasgupta, & Gilbert Cote, 2010; Asgari, Dasgupta, & Stout, 2012; Aspinwall, 1997; Blanton, 2001; Dasgupta, 2011; Davies, Spencer, & Steele, 2005; Haines & Kray, 2005; Hoyt & Blascovich, 2007; Lockwood, 2006; Lockwood, Jordan, & Kunda, 2002; Lockwood & Kunda, 1997; Marx & Roman, 2002; McIntyre, Paulson, & Lord, 2003; Seta, 1982; Wood, 1989). They also have the potential to affect observers' attitudes toward a given domain and participation in that domain because they exemplify that attitude (Dasgupta, 2011). For example, children often learn the value of being generous by observing role models who are generous. When adults behave generously, children tend to also behave generously (Rushton, 1975).

Given that role models exert profound influence on the way people learn, the challenge is how to present role models in such a way that students actually attend to them in schools. Extensive research has shown that people attend to role models who possess the following characteristics: (a) they display competence (Williamson, Meltzoff, & Markman, 2008), (b) they succeed on goals that are construed as attainable (Lockwood & Kunda, 1997, 1999), and (c) they are viewed as relevant or similar to the self (Goethals & Darley, 1977; Markus & Kunda, 1986; Markus & Nurius, 1986; Markus & Wurf, 1987; Wood, 1989). In the present study, we incorporated these characteristics into the scientists' stories. For instance, in order for the scientists to be viewed as competent, we chose well-known scientists who accomplished great feats. The other two features of the scientists (the attainability of their goals and their relevance to students) were emphasized by disclosing how these scientists failed and struggled in both life and intellectual domains. This is unique because role models are often used to demonstrate heroic actions and morals, but here we use role models to reveal famous scientists' limitations and how to work through such limitations. By doing this, we hoped to confront students' belief that scientists are simply geniuses who do not need to work hard (Carey, Evans, Honda, Jay, & Unger, 1989; Dweck, 2010; Schoenfeld, 1988).

However, simply exposing students to sequences of a role model's actions does not guarantee that role models will have an impact on people's attitudes and behaviors. It is crucial that explanations and descriptions accompany the actions and behaviors of role models (Bandura & Mischel, 1965; Berg & Bass, 1961; Hovland, Janis, & Kelley, 1953) to have a lasting impact. For instance, hearing a model explaining why he or she persisted and how confident he or she was that persisting would lead to success in a complex task exerted a larger influence on children's subsequent persistence than simply seeing the model persist on challenging tasks (Zimmerman & Ringle, 1981). For these reasons, we used role models plus stories that explained the importance and processes of persisting.

To sum up, using stories in educational settings is not a new practice. However, using stories of scientists to model struggles and failures in order to increase high school students' effort in science learning is unique for the following reasons. First, exemplifying the message that effort pays off through role models' struggles is a different approach from directly lecturing about the importance of effort or providing physiological evidence of how the brain grows through effort (See Dweck, 2006, 2010). Because role models in the stories allow students to vicariously experience struggle through failures, we hope it would increase their effort that is needed for successful performance. Second, using stories to instruct adolescents is not common. Based on our pilot studies, students expressed that stories are often given to younger students. However, this approach largely disappears after middle school age, even though high school students express a strong thirst for hearing stories about people who create the knowledge that they are learning. Finally, the effect of stories on motivation and science classroom performance has rarely been systematically and empirically tested in everyday science classes, even although educators often use stories to motivate and inspire students' interests in a given topic. A vast majority of studies on the effect of stories has been interview-based and qualitative. In order for this approach to be replicated, we need more empirical evidence. For example, previous research has identified the effectiveness of struggle stories versus achievement stories (H. Hong & Lin-Siegler, 2012). However, this research study has not examined which types of struggles could have more profound impact on students' motivation and science learning.

The Current Study

The current study pursued four goals. The first goal was to differentiate between two types of scientists' struggle stories—intellectual and life struggles—and to compare the effects of these stories with those about scientists' achievement as they appear in school textbooks. One possibility is that intellectual struggles are more effective because they are directly relevant to students' struggles with their schoolwork. Alternatively, students would find life struggles more motivating because life struggles humanize scientists and thereby make them more relatable to students. The achievement stories controlled for the possibility that simply learning about scientists was the key, rather than learning about their struggles.

The second goal was to replicate and extend findings from the study conducted by H. Hong and Lin-Siegler (2012) using the same struggle message and story structure with a different population, different instructional materials, and different measures. Although the Hong and Lin-Siegler study demonstrated an effect among the Taiwanese high school student population, the current study focuses on a predominantly low-income, minority population of American high school students. We developed new stories about different scientists' struggles and measured school learning outcomes, rather than problem-solving skills in a computer simulation program. To the best of our knowledge, this is the first study to examine and demonstrate causal effects between learning about famous scientists' struggle stories and improvement in students' motivation and science learning outcomes in everyday school settings.

The third goal was to examine the effects of the struggle stories on students' motivation, using both learning outcomes and a series of well-established motivational measures. As behavioral measures, we used science-class grades. This was preferable to the common practice of using GPAs or standardized test scores because science-class grades more directly reflect students' motivation to learn science and better captures the process of learning (Ames & Archer, 1988; Touré-Tillery & Fishbach, 2014). We also included the battery of motivational measures developed by Dweck and her colleagues (Blackwell et al., 2007) to measure mind-set. This inventory measures students' beliefs about intelligence, effort, goal orientation, and attributions regarding failure. In addition, we conducted interviews with half of the students regarding whether and in what way they felt connected to the stories and scientists.

Our specific predictions were as follows: First, we predicted that reading struggle stories (either about life or intellectual struggles) would be more effective in improving students' everyday science-class performance than reading achievement stories. Second, we predicted that reading about struggle stories (either about life or intellectual struggles) would affect students' general motivation in terms of (a) their beliefs about intelligence (i.e., students who read about struggle stories would be more likely to believe that intelligence can be increased through effort than those who read about achievement stories), (b) their beliefs about effort (i.e., students who read about struggle stories would be more likely to believe that effort is important for success than those who read about achievement stories), (c) their goal orientations (i.e., students who read about struggle stories would be more oriented to learning that welcomes challenging work than those who read about achievement stories), and (d) their attributions regarding failure (i.e., students who read about struggle stories would show less helpless attributions to failure and more effort-focused responses to failure than those who read about achievement stories). For this study, we used domain-general, rather than domain-specific, motivation measures because we wanted to test whether our intervention was strong enough to have an impact on general motivation before tackling domain-specific motivation. And, finally, we predicted that students who read about struggle stories (either about life or intellectual struggles) would feel more connected to the stories and the scientists than those who read about achievement stories.

Our fourth goal was to investigate whether students of different performance levels derive similar benefits from learning about how scientists struggle to succeed. Low-performing students might benefit most from the intervention, because they most often need to persist in the face of failure. On the other hand, everyone fails sometimes, so all students might benefit equally from the intervention. In sum, through these various dependent measures, we tested whether our intervention (introducing stories about scientists who struggled through life and intellectual failures) impacts students' science learning in the classrooms.

Method

Participants

A total of 472 9th and 10th grade students enrolled in science classes from four high schools in a large, urban school district participated in the study. Although these schools served a diverse group of students, all four schools received A or B "Overall Grade" ratings (an indicator summarizing student progress, student proficiency, and school environment) from their district in the 2012 progress report, (New York City Department of Education, n.d.; School Quality Reports, 2011–2013).

From an initial sample of 472, we limited our analysis to participants who participated in at least one day of the 3-day intervention program and for whom science grades were available for the 6 weeks before and after the intervention. Our final sample included 402 students (60% male, 40% female; $M_{\text{age}} = 16.01$, $SD_{\text{age}} = 1.29$). Most students were from low-income families (71.7% were eligible for free or reduced lunch) and minority groups (36.8% Latino, 31.4% Black, 11.5% Mixed or Biracial, 8.2% Asian, 7% White, and 5% Other). Participants were mostly native English speakers, but 18.4% reported being born outside of the United States and 31.8% reported speaking English only half the time or less at home.

Procedure and Study Design

Students participated in our study during the school day in their science classes. The intervention lasted 5 weeks. In the first week, students received pretest measures which was a short survey assessing beliefs about intelligence, effort, goal orientation, and attributions regarding failure.

After the pretest, students from each class were randomly assigned to read and respond to one of three scientist's stories: (a) intellectual struggle stories (ISS; $n = 131$), (b) life struggle stories (LSS; $n = 136$), and (c) achievement stories (AS; $n = 135$). Students in the ISS condition read about the intellectual struggles that the three scientists (Albert Einstein, Marie Curie, and Michael Faraday) experienced during their scientific discoveries. Students in the LSS condition read about struggles of the same three scientists, but the stories focused on the difficulties they experienced in their personal lives, such as poverty and having to flee the Nazis. Finally, students in the AS condition read stories about the three scientists' achievements (see the Materials section for full descriptions of the stories).

The story condition was randomized at the student level, so students within the same class received different versions of the story (ISS, LSS, or AS). The order of scientists was randomized at the classroom level, so that students in the same class would read about the same scientist in any given session.

Then, in the final week, a week after intervention, they received a posttest, which consisted of the same measures as the pretest (e.g., beliefs about intelligence, effort, goal orientation, and their attributions regarding failure).

Materials

All scientist stories were of similar length, format, and structure. Each story was approximately 800 words in length and formatted into two double-spaced pages. The three conditions were reflected in the title and content of the stories. The ISS condition was titled "Trying Over and Over Again Even When You Fail" and focused on intellectual hurdles and challenges. The LSS condition was titled "Overcoming the Challenges in Your Life" and focused on struggles in one's personal and family life. The achievement (AS) condition was titled "The Story of a Successful Scientist" and focused primarily on scientific accomplishments. Given three conditions and three scientists, a total of nine stories were developed.

The three scientists (i.e., Albert Einstein, Marie Curie, and Michael Faraday) were chosen to include both genders and varying levels of familiarity. On the pretest, 86% of students reported having heard of Albert Einstein, 35.1% of Marie Curie, and 6.6% of Michael Faraday.

All stories had a similar structure. The first paragraph introduced the accomplishments of the scientist and the main point of the story (which reflected the condition). The three paragraphs provided examples to support this main point. The last paragraph reiterated the main point. The achievement-oriented and struggle-oriented information about each scientist was adapted from biographical or autobiographical sources (e.g., Einstein, 1956; Hamilton, 2004; Schlipp, 1951; Steele, 2006). The intellectual and life struggles that were included reflected the *Oxford English Dictionary*'s definition of *struggle*: "strive[ing] to achieve or attain something in the face of difficulty or resistance." The achievement-oriented stories described each scientist's important discoveries and awards, as well as historical events related to the major discoveries.

Assessments of the nine stories confirmed comparable sentence lengths, word counts, vocabulary levels, and reading ease, as measured by the Flesch (1948) Reading Ease metric, ensuring that content difficulty and overall readability was comparable across all conditions as well as compatible with students' literacy level (Table 1 provides examples from each of the three conditions).

Measures

Science-class performance measures. For the reasons described previously, students' science-class grades at the end of the 6-week grading periods before and after the intervention served as our performance measure. Teachers reported that these grades were based on a combination of classwork, homework, quizzes, projects, and tests. Grade averages were transformed into *z* scores within each class, such that scores accurately represented students' science performance relative to other students within their class, regardless of the teacher's grading standards.

Beliefs about intelligence measure. A total of six items assess students' beliefs about intelligence (see Blackwell et al., 2007; Y. Y. Hong et al., 1999; Levy & Dweck, 1997). Students' beliefs that intelligence can be increased through effort were assessed by their level of agreement with statements such as "You can learn new things, but you can't really change your basic intelligence" and "You can always greatly change how intelligent you are." Responses were expressed on a 6-point Likert scale ranging from 1 = *strongly agree* to 6 = *strongly disagree*. Scores of some items were transformed so that higher scores indicated a more incremental belief about intelligence. Cronbach's alpha was .82 for the pretest and .84 for the posttest.

Beliefs about effort measure. The nine items used to assess students' beliefs about effort were drawn from a measure used by Blackwell et al. (2007). Sample items include statements such as "If you're not good at a subject, working hard won't make you good at it" and "If an assignment is hard, it means I'll probably learn a lot doing it." Students, again, indicated their level of agreement on a 6-point Likert scale ranging from 1 = *strongly agree* to 6 = *strongly disagree*. Responses, again, were coded so that higher scores consistently indicated stronger belief in effort. The original nine-item scale was reduced to seven items to increase internal consistency. Cronbach's alpha was .76 for the pretest and .77 for the posttest.

Goal orientation measure. Items drawn from the Task Goal Orientation subscale of the Patterns of Adaptive Learning Survey (Midgley et al., 1998) were used to measure goal orientation for schoolwork. For our purposes, only mastery goals, not performance goals, were measured, as we were more interested in whether the intervention condition had an effect on the former rather than latter goals. Thus, students indicated their level of agreement to statements such as "An important reason why I do my schoolwork is because I like to learn new things" and "I like schoolwork best when it makes me think hard" on a 6-point Likert scale ranging from 1 = *strongly agree* to 6 = *strongly disagree.* Cronbach's alpha was .82 for the pretest and .83 for the posttest. Items were, again, recoded such that higher scores consistently indicated a learning-focused orientation that welcomes challenging work.

Attributions regarding failure measure. Two measures adapted from Blackwell et al. (2007) assessed students' attributions and planned behavioral responses to a hypothetical scenario:

> You start a new class at the beginning of the year and you really like the subject and the teacher. You think you know the subject pretty well, so you study a medium amount for the first quiz. Afterward, you think you did okay, even though there were some questions you didn't know the answer for. Then you got your quiz back and you find out your score: you only got a 50%, and that's an F.

After reading this scenario, students responded to the following sets of items.

Nonhelpless attributions. Five statements assessed whether students' attributions of this hypothetical failure reflected a belief that this failure was caused by a lack of ability. Items included

Table 1
Story Content Examples

	Albert Einstein	Marie Curie	Michael Faraday
Achievement story (AS condition)	Albert Einstein won many awards in his life, including the 1921 Nobel Prize in physics. His thoughts were so advanced that many contemporary scientists are still working on the ideas he talked about in 450 papers he published. In 1999, *Time* Magazine named Einstein the man of the century, and he is considered the father of modern physics because of his achievements.	By the time she reached college, Marie Curie was able to understand five languages: Polish, Russian, German, French, and English—all of which were the major languages that top scientists spoke at the time. Curie attended the top college in France, the Sorbonne. Not only was she the first woman to receive a degree in physics there, she was also selected for a prestigious award when she graduated.	Michael Faraday was described as one of the greatest experimental scientists who ever lived in history. He made immense contributions that formed the basis of the fields of electricity, electromagnetism, and electrochemistry. He was one of the first scientists to see that electricity and magnetism were not isolated phenomenon but part of a unified force of nature.
Intellectual struggle story (ISS condition)	Bearing in mind that to succeed, one has to try things over and over again when mistakes or failures happen, Einstein rewrote his papers and improved his arguments when people disagreed with him. For instance, when theorizing that gravity from a large object like a planet could actually bend light, Einstein received many questions and doubts. Although he could not conduct any experiments to support what he proposed, he knew his ideas so well that he was still able to debate with others.	It was frustrating that many experiments ended up in failure; however, Curie would not let herself stay sad for too long. Instead, she returned to where things did not work out and tried again. Often working hour after hour and day after day, Curie focused on solving challenging problems and learning from her mistakes. She knew that the way of progress was never easy, and later, she said, "I never yield to any difficulties."	Sometimes, months of experimenting ended up nowhere. However, the failures on one occasion did not stop Faraday from investing his efforts on other occasions. For example, many scientists at that time wanted to develop a machine that could change electricity into the motion of a wheel, but none of them were able to make that happen. Faraday did not succeed at the beginning, either. But after going through a number of trials and errors, he eventually developed a device that could work.
Life struggle story (LSS condition)	Growing up, Einstein saw his father struggle to provide for the family. Looking for work, Einstein's father moved the family several times for different jobs. This meant that Einstein had to change schools more than once during his childhood. Moving between schools was very difficult. Einstein not only felt out of place, but it was always challenging for him to catch up to what his new class was working on.	Going to college was hard for Curie because at that time, people did not approve of women going to school. Thus, Curie had to study at secret classes. What's worse, when the government of Russia controlled Poland, no schools in Poland were allowed to accept any women. For this reason, Curie had to travel to another country, France, to receive education.	Many of the other scientists were university-educated gentlemen from the upper class who were members of the Church of England. Faraday was from a poor background and his family was part of a religious minority group. Because of this, he had to face a lot of class and religious prejudice. After many years of struggle, Faraday became a scientist and got his own lab.

statements such as "*I wasn't smart enough*" and "*The test was unfair.*" Students were asked to indicate their level of agreement with each statement ranging from "1" = *strongly agree* to "6" = *strongly disagree*. Items were recoded such that higher agreement indicated a less helpless, more proactive response to failure. One item was removed from the original scale to improve internal consistency. Cronbach's alpha was .74 for the pretest and .80 for the posttest.

Response to failure. Five other items were employed to assess students' endorsement of potential behavioral responses to the hypothetical failure. Items include statements such as "I would spend more time studying for tests" and "I would try not to take this subject ever again." Students indicated the likelihood of pursuing the specified behaviors using a six-point Likert scale ranging from 1 = *strongly agree* to 6 = *strongly disagree*. Responses were recoded such that higher scores consistently indicated higher endorsement of effort-focused responses to failure. Cronbach's alpha was .73 for the pretest and .76 for the posttest.

Connectedness to stories and scientists. Half of the students were interviewed regarding whether and in what way they felt connected to the stories and each of three scientists. The questions were open-ended and we allocated 1 point for every scientist that students reported feeling connected to. In other words, the points allotted ranged from 0 to 3, such that the maximum point a student could receive was a "3" (indicating he or she reported feeling connected to all three scientists) and the minimum point a student could receive was a "0" (indicating he or she reported not feeling connected to any of the scientists).

In terms of analyzing in what way students connected (or did not connect) to the stories and scientists, we used the constant comparative methods of data analysis to capture recurring themes that surfaced from students' responses (Glaser & Strauss, 1967).

Results

Effect of Stories on Science Class Performance

Between-subjects effects. There were no differences in science performance in the prior grading period across the three conditions, $F(2, 399) = 1.43$, $p = .24$; thus, randomization was successful. Means and standard deviations for all three conditions are presented in Table 2.

Next, we assessed the effects of the story intervention on students' science-class grades, which were standardized into *z* scores[1] within each class for purposes of comparison. Controlling for students' science grades prior to the intervention, there was a main effect of story condition on postintervention science-class performance, $F(2, 398) = 3.15$, $p = .04$, $\eta_p^2 = .02$. Planned comparisons indicated that students in the AS condition ($M = .08$, $SD = 1.02$) had lower science grades than students in either the ISS condition ($M = .12$, $SD = .81$), $t(398) = 2.28$, $p = .02$, $d = .04$, or the LSS condition ($M = .17$, $SD = .90$), $t(398) = 2.04$, $p = .04$, $d = .05$. There was no difference between grades in the latter (ISS or LSS) conditions ($p = .79$).

Within-subjects effects. We also tested whether there were differences between the pre- and postintervention science-class grades within each condition. The direction of change was as predicted, with higher grades after the intervention in both struggle story conditions (Table 2), but the differences were not significant in either the ISS condition, $t(130) = -1.39$, $p = .17$, or the LSS condition, $t(135) = -.69$, $p = .51$. However, students in the achievement condition had lower science grades postintervention from preintervention, $t(134) = 2.48$, $p = .01$, $d = .16$.

Effect of Story Intervention on Motivation

We first examined how beliefs about intelligence, effort, goal orientation, and attributions regarding failure were related to science-class grades before and after the intervention. Second, we considered whether the story intervention affected students' self-reported responses on any of these measures.

Correlations among science performance and motivational variables. Table 3 presents the correlations between students' science grades and our battery of motivational measures at both pretest and posttest. On the pretest, there was a small but significant positive correlation between science grades and students' beliefs about effort ($r = .19$), goal orientation ($r = .11$), and positive strategies in response to failure ($r = .10$). The same pattern appeared in the posttest correlations; science grades correlated with beliefs about effort ($r = .15$), goal orientation ($r = .15$), and positive strategies ($r = .14$). The science grades, however, were not correlated with beliefs about intelligence or response to failure at either time point. Within both the pretest and posttest, correlations among the motivational belief measures were moderate and positive, ranging between .27 and .63.

Between-subjects effects. To test whether story intervention affected students' responses on any of the motivation measures, we first determined whether there were preexisting differences among the three conditions on these measures. Our analysis revealed no group differences on the pretest measures (all *F*s < 1).

We next conducted a MANCOVA, entering each of the five motivation measures as dependent variables, to test whether there was an effect of stories using the pretest scores as covariates to control for prior students' beliefs. As shown in Table 2, we did not find any effect of story intervention on the motivation measures, $F(10, 596) = .73$, $p = .70$, Wilk's $\Lambda = 0.98$. Thus, further follow-up analysis was not conducted.

Effect of Story Intervention on Students With Different Prior Performance Levels

Although we found a main effect of the intervention (i.e., that students who read about either struggle stories had significantly higher science-class grades than those who read about scientists' achievements), we wanted to further determine whether the effect of story intervention differed based on students' prior class performance (low vs. high performers) when measuring their postintervention class performance. We used a multiple regression analysis predicting postintervention class performance from condition[2] (control, struggle story) and preintervention class performance, and their interaction. This model was significant, $F(3, 398) = 136.54$, $p < .001$, $R^2_{adj} = 50.3\%$, and there was a significant interaction effect of story intervention by preintervention class performance, $\beta = -.15$, $t(398) = -2.46$, $p = .01$.

As depicted in Figure 1, students who read about struggle stories and had lower preintervention grades (1 *SD* below the mean) had higher postintervention grades than students who also had lower preintervention grades but read achievement stories, $t(398) = 3.52$, $p = .001$. Conversely, there was no effect of story intervention for those who had high preintervention grades (1 *SD* above the mean), $t(398) = .14$, $p = .89$. This suggests that story intervention does not have an effect for students who had high preintervention grades. Instead, story intervention is beneficial for students who had low preintervention grades.

Connectedness to Stories and Scientists

Quantitative interview analysis. To test whether more students felt connected to the stories and scientists as a function of story intervention condition, we conducted an ANOVA, entering the tallied number of scientists students felt connected to as the dependent variable and condition as the independent variable. We observed a main effect of condition, $F(2, 196) = 5.05$, $p = .007$, $\eta_p^2 = .05$. Planned comparisons indicated that students in the AS condition ($M = 1.41$, $SD = .93$) felt connected to less scientists than students in the ISS condition ($M = 1.90$, $SD = .93$), $t(144) = 3.19$, $p = .002$, $d = .53$, or the LSS condition ($M = 1.75$, $SD = 1.03$), $t(127) = 1.99$, $p < .05$, $d = .35$. There was no difference in connectedness in the ISS or LSS conditions ($p = .42$). This suggests that more students felt connected to the scientists after reading about struggle stories (intellectual or life) than stories about achievement.

Qualitative interview analysis. An analysis of interviews with students regarding in what way they felt connected to the stories and the scientists revealed several themes that varied across intervention condition. We will report recurring themes within each condition in the subsequent paragraphs.

When students in the AS condition reported that they did not feel connected, the most frequently occurring theme centered on

[1] These *z* scores were calculated within each class, meaning that zero represents the class mean, based on grades from all students, even those not participating in the intervention. This was done to represent performance relative to all classmates. Average *z* scores were positive in all three groups, suggesting that the nonparticipating students were lower performing on average.

[2] To ease interpretation, we compared the achievement condition group with a combined struggle condition (both life and intellectual struggles).

Table 2
Pre- and Postintervention Means and ANCOVA Results

Variable	Intellectual struggle condition $n = 131$		Life struggle condition $n = 136$		Achievement condition $n = 135$		ANCOVA *F*-test (effect of condition on posttest controlling for pretest)	
	M	*SD*	*M*	*SD*	*M*	*SD*	*F*	η_p^2
Science performance (*z* score)								
Pretest	.04	.80	.13	.92	.22	.88		
Posttest	.12	.81	.17	.90	.08	1.02	3.15*	.02
Beliefs about intelligence								
Pretest	4.54	1.06	4.45	.92	4.44	.96		
Posttest	4.70	.99	4.47	1.01	4.54	.94	1.37	.009
Beliefs about effort								
Pretest	4.72	.70	4.65	.85	4.55	.79		
Posttest	4.63	.80	4.61	.88	4.59	.83	.54	.003
Goal orientation								
Pretest	4.27	1.08	4.26	1.05	4.17	1.21		
Posttest	4.20	1.15	4.28	1.16	4.15	1.11	.24	.002
Nonhelpless attributions								
Pretest	4.28	.87	4.26	.93	4.30	.98		
Posttest	4.28	.99	4.26	1.02	4.11	1.09	1.68	.01
Response to failure								
Pretest	5.06	.68	5.03	.71	5.05	.74		
Posttest	5.01	.74	4.90	.74	4.89	.86	.99	.006

* $p < .05$. ** $p < .01$. *** $p < .001$.

achievement issues. For example, one student said:, "There is nothing to connect to because it was all about his [Einstein's] achievements and what places he [Einstein] went to, which I have not done." On the other hand, when students felt connected, the theme centered on innate abilities. For example, one student said, "I can connect with him being brilliant at 5 years old because I was, but I was too lazy to go forward." These statements frequently echoed with how other students in the same condition responded when they did and did not feel connected.

When students in the LSS condition reported that they did not feel connected, the most frequently occurring theme surrounded issues of external experiences and cultural differences. For instance, one student said, "No, because I do not come from poverty and in today's world, there is much less discrimination." Conversely, when students felt connected, the major theme that arose was issues concerning internal experiences and personal family life. One student said, "I felt connected to Curie. Yes, I also went through an ordeal, when I first moved to U.S. There was only me and my mom in the country. We lived in a no heat apartment for one winter, everything in the room was frozen." Such responses were reflective of how other students within the LSS condition connected or did not connect to the stories and scientists.

And, finally, when students in the ISS condition did not feel connected, the major theme that surfaced was students' lack of interest in science in general. One student said, "No, not really because the chemistry behind her work doesn't interest or concern me." And when students felt connected, a major theme that emerged was their connection to the scientists overcoming failures. For example, one student said, "Einstein's curiosity and how he never gives up on what he believes are what I feel connected to." These responses also reiterated how other students felt when they did (or did not) connect to the scientists and stories.

These results generate several insights that deserve attention. First, connection varies as a function of story type—far fewer students feel connected when the stories are about scientists' achievements. Second, we suspect that the struggle stories re-

Table 3
Correlations Among Science Performance and Motivation Measures

	Science performance (*z* score)	Beliefs about intelligence	Beliefs about effort	Goal orientation	Nonhelpless attributions	Response to failure
Science performance (*z* score)	—	.05	.19***	.11*	.02	.10*
Beliefs about intelligence	.03	—	.43***	.34***	.27***	.31***
Beliefs about effort	.15**	.47***	—	.57***	.42***	.52***
Goal orientation	.15**	.30***	.564***	—	.22***	.41***
Nonhelpless attributions	.07	.39***	.58***	.40***	—	.45***
Response to failure	.14*	.35***	.63***	.52***	.50***	—

Note. Pretest correlations are shown above diagonal; posttest correlations are presented below the diagonal.
* $p < .05$. ** $p < .01$. *** $p < .001$.

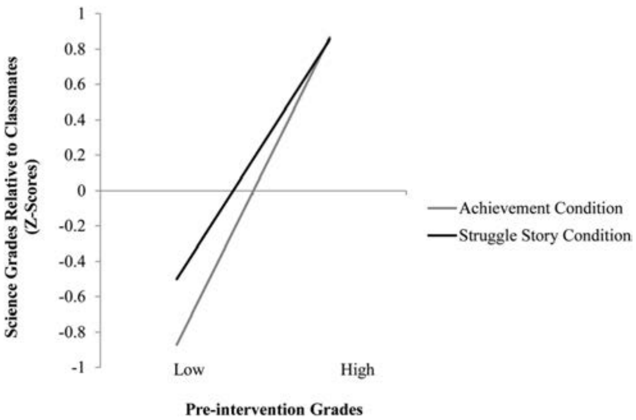

Figure 1. Effect of story intervention on students with different prior performance levels. The graph presents the effect of story intervention (achievement and struggle stories) on students' postintervention class performance depending on students' prior class performance (low vs. high performers). The class performance prior to the intervention is based on ±1 *SD* of the average science grade before the intervention began.

vealed scientists' vulnerability, namely, their failures in their experiments and failure to receive social recognition and appreciation, which in turn creates a sense of connection between the students and scientists who are often viewed as being untouchable. Such a link would support existing research that has shown that vulnerability enhances feelings of connectedness (Aron, Melinat, Aron, Vallone, & Bator, 1997; Collins & Miller, 1994; Wright, Aron, & Tropp, 2002).

Discussion

The results from this study support several hypotheses. First, exposing students to scientists' struggle stories improved their science-class performance (in terms of class grades), whereas exposing students to achievement stories did not. Not only did class performance not improve, reading achievement stories might actually be harmful, as reflected in our results.

Second, students respond to the presence of struggle in the scientist stories, but whether the struggles centered on life or intellectual struggles did not seem to alter the effects of the stories on science-class performance. Both the ISS and LSS conditions were superior motivators compared with the scientists' achievement condition. There are many reasons as to why struggle stories are effective, which will be discussed in the following section.

Third, our intervention was most beneficial for students who are low performing. For low-performing students, the exposure to struggling stories led to significantly better science-class performance than low-performing students who read achievement stories. Future research should identify other individual differences among students that might also benefit from this intervention.

Fourth, a significantly larger number of students who read about scientists' struggles (intellectual or life) felt connected with the stories and scientists than did students who read about scientists' achievements. The interviews with the students revealed that emphasizing the scientists' innate intelligence discouraged students from feeling connected with the stories or the scientists. The stories that revealed failures and scientists' vulnerability through their struggles enhanced connectedness between the students and the scientists. It would be worthwhile to investigate in future research how potential role models are described may lead to different types of connectedness between students and instructional material.

Finally, although results from our science-class performance measure were promising, the findings from our series of motivation belief measures were more equivocal. One explanation for this is that the purpose of the current intervention was to model the message that effort can grow intelligence and ability. And because the intervention instruction did not explicitly target students' beliefs about intelligence, students had to draw inferences from the portrayal of struggling scientists to the idea of adopting a growth mindset, which is a challenging business in all educational research. It was not surprising that there was no intervention effect on students' beliefs about intelligence. The implications associated with these outcomes, limitations of the study, and future directions are discussed in the following section.

Implications, Limitations, and Future Research Directions

Our findings have implications for several areas, particularly for (a) motivation in science learning, (b) beliefs education and science-class performance, and (c) instructional design.

Motivation in Science Learning

Highlighting struggle as a normal part of learning is especially important in the science domain because of (a) the common belief that success in science requires exceptional ability (H. Hong & Lin-Siegler, 2012; Safdar, 2013; Shumow & Schmidt, 2014; R. Stinebrickner & Stinebrickner, 2008; T. R. Stinebrickner & Stinebrickner, 2011, 2013), and (b) the inevitable repeated failures involved while designing scientific experiments (Shumow & Schmidt, 2014). The message that even successful scientists experience failures prior to their achievements may help students interpret their difficulties in science classes as normal occurrences rather than a reflection of their lack of intelligence or talent for science.

Efforts to increase students' motivation to learn science tend to emphasize the successful aspects of the scientists' achievement with little information about the struggles that led to those discoveries. This failure-reduction approach to science education is reflected in school textbooks. Recently, we reviewed 21 science textbooks used by 6th through 11th grade students in New York City public schools and found that there was limited information about scientists. In one textbook we reviewed, Albert Einstein was described as "the most powerful mind of the twentieth century and one of the most powerful that ever lived . . . He was the most different from any other men" (Hewitt, 2006, p. 715). Such portrayals can only decrease the likelihood of students pursing science (Beardslee & O'dowd, 1961; Souque, 1987). To further investigate this issue, we are currently conducting a systematic content analysis of science textbooks to see how content knowledge and scientists are presented to students.

Because overcoming failure is a natural part of science learning, the current study attempted to present students a realistic picture of doing science by emphasizing failure and the amount of effort required to succeed in science. Most educational interventions seem to help high-performing students more than low-performing students (White & Frederiksen, 1998). Yet the effect of our intervention was more pronounced for low-performing students. The reason that our intervention was particularly effective for low-performing students could be because these students might have felt more inspired by the message that even famous scientists have struggled. Future studies should identify other types of motivational messages that would be particularly beneficial for low-performing students.

Beliefs Education and Science Class Performance

A surprising outcome from our study was that the exposure to scientists' struggle stories did not affect students' general beliefs about intelligence and effort. In addition, these general beliefs were only minimally related to students' science-class performance. These findings are especially interesting because the links between beliefs about intelligence and academic performance has been established in a number of previous studies (e.g., Blackwell et al., 2007; Mangels, Butterfield, Lamb, Good, & Dweck, 2006; Mickkovska, 2010; Nisbett et al., 2012). One explanation for our findings is that students' behaviors were more subject to change than students' beliefs. For instance, research showed that teaching undergraduates about civil rights and equality in society resulted in immediate behavior changes (e.g., participants showed increased interaction with minority students and expressed interest in the advancement of the minority population). Yet corresponding beliefs and attitudes did not change significantly (cited from Ball-Rokeach, Rokeach, & Grube, 1984; Gray & Ashmore, 1975; Grube et al., 1994; Rokeach, 1973). In addition, among studies that produced belief change, the key element that induced change was by providing specific feedback and interpretations of people's current belief systems, thereby inducing a state of dissatisfaction with one's original beliefs (Grube et al., 1994; Rokeach, 1973; Rokeach & Grube, 1979). Relatedly, other studies provided corresponding evidence that significant changes in both belief and behavior were observed when participants have strong self-belief dissatisfaction (Hamid & Flay, 1974). Unfortunately, most of the studies, including the current study, on beliefs, motivation, and school performance, failed to consider students' self-belief dissatisfaction as a mediating variable. Thus, future studies should measure effects of interventions on students' self-dissatisfaction about their existing beliefs, and academic learning.

Another explanation has to do with the domain-specific beliefs in motivation. General beliefs about intelligence can be distinct from beliefs about intelligence in science (Dweck & Master, 2009; Stipek & Gralinski, 1996). As a result, the general measures of motivation belief used in this study may have failed to capture changes in beliefs about intelligence in science that could have driven the changes in the student performance we observed. Further research is needed to investigate the relationship between belief and performance using domain-specific measures across different domains.

Instructional Design

Instruction in science classrooms is largely designed to teach students about content knowledge and problem-solving skills. Content-focused instruction is undoubtedly important because content knowledge and problem-solving skills are used to evaluate students' learning. However, the quality of content instruction is not the sole factor that affects science learning (Shumow & Schmidt, 2014). Just as important, students need to be motivated enough to pay attention to the content instruction (H. Hong & Lin-Siegler, 2012). Our results suggest that students perform better when messages about effort enabling success are highlighted in science classes. The majority of motivation interventions have not explicitly manipulated specific features of the instruction that can impact students' motivation and learning in science classes.

Additionally, instructional motivation has not extensively incorporated and investigated the impact of role models in classroom-based interventions. Prior research on role models has shown that important mediating variables to affect individuals' performance and motivation are the domain relevance of the role model's achievement to the self and also the perceived attainability of the role model's successes (Lockwood, 2006; Lockwood & Kunda, 1997). We add to this literature by investigating another important variable that deserves more attention: emotional connectedness to the role model's vulnerability. Our results showed that students who read about struggle stories felt connected to more scientists than students who read about scientists' achievements. Future studies can further examine the link between connectedness to the role models and its effect on students' performance.

Limitations and Future Directions

There are several limitations to the current study. The first is that although the intervention significantly impacted students' science performance relative to their peers, the effect size is small. Factors contributing to this might include (a) the length of the intervention, (b) the low-interactive design of the story instruction, and (c) the fact that struggle messages were not designed to target a particular content or problems that students were facing at that moment. Although realism is an advantage in the current study, because results reflected actual learning and performance in classrooms, the quality control of the content instruction was a challenge. Because we were collecting data in the field, we could not guarantee that students in each condition received the same number of stories and the same intervention quality. Effects were also examined among a relatively heterogeneous population and their actual performance in science classes. Given these limitations, the fact that such an unobtrusive, field-based intervention led to any effect on students' performance is encouraging. Future studies should examine whether teacher-led struggle stories that are more incorporated into the classroom goals and activities will result in larger effects.

Another limitation of this study is that the mediating factors leading to the observed benefits were not completely unpacked. Although belief and attribution measures were used in the present study, they did not adequately capture the psychological process through which these domain-specific performance differences emerged. Our analyses from interviews with students revealed that the driving mechanism of our intervention effects is most probably feeling connected to the stories and scientists. That is, we speculate that the struggles of scientists exposed their vulnerabilities, which in turn enhanced feelings of connectedness between the students and the scientists. Future research should continue to explore this link, expanding upon shared identities and affiliations with the scientists, that is, in terms of shared gender and/or race, and so forth.

According to intergroup literature, having shared identity promotes more cooperative means and efforts and a sense of affiliation and like-mindedness between in-group members relative to out-group members (people who do not share the same identity; see Brewer, 1979; Tajfel, Billig, Bundy, & Flament, 1971; Tajfel & Turner, 1979). Based on this work, we can infer that sharing ethnic matches with the scientists might have a more potent intervention effect whereas not having a match might be less of an impact. We can only speculate this might be the case, as we did not consider whether there was a match or mismatch between the scientists or students in this study, but this is certainly a research endeavor we can pursue to unpack additional mechanisms.

Additionally, a methodological limitation is that the motivation measures asked explicit questions about intelligence and effort, which may lead to issues, such as experimental demand and self-consciousness, that are associated with the use of explicit measures (Banaji & Greenwald, 1995). We suspect that implicit, domain-specific measures of beliefs about intelligence and effort in science will offer more insight into the mechanisms through which struggle stories impact performance (see Banaji & Greenwald, 1995; Klein, Wesson, Hollenbeck, & Alge, 1999). Currently, we are testing domain-specific measures in a series of classroom studies.

Finally, questions remain as to the implementation and duration of the intervention effects. Even though students benefited from receiving the full, three-session program, the existing individual differences (e.g., low-performing students tend to have more absences and be less interested in science) among students may have influenced our outcomes despite controlling for students' pretest science grades. Furthermore, outcomes were demonstrated across a 6-week marking period, which, although not an insignificant amount of delay in time, cannot answer whether these stories continued to shape student performance toward the end of the school year or beyond. Future work can extend the present study by examining (a) how long these effects last, (b) factors related to implementation of the program (e.g., manipulating the numbers of sessions), and (c) the impact of having teachers facilitate this approach.

Conclusion

In conclusion, the trend of motivation research in recent years has shifted from a creation of "broad, all-encompassing" theories to a focus on the analysis of specific aspects of motivated behavior (see Graham & Weiner, 1996). In addition, there is a shift from studying motivation in the lab to school settings. The current study builds on this work by focusing on a specific aspect of attribution theory of motivation that has not been studied in school settings—using story-based instruction to model scientists' struggles in their learning and work. Confronting students' beliefs that science learning requires exceptional talents and abilities offers new instructional approaches to improve motivation and science learning. Specifically, highlighting scientists' struggles enhances the effectiveness of such instruction. These approaches can be implemented in classrooms to improve motivation and learning in science, and likely other subjects as well.

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