Dangers of a Fixed Mindset: Implications of Self-theories Research for Computer Science Education

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ABSTRACT

Psychology studies have shown that students' beliefs about their own intelligence—whether they view intelligence as fixed or malleable—have an important influence on student development and achievement. Yet the impact of these theories on success in Computer Science (CS) has not been directly investigated. Self-theories research has shown that students with a *fixed mindset* are more likely to exhibit a helpless response to substantial challenges and to experience decreases in self-esteem during college. Those with a *growth mindset* welcome challenges, displaying a mastery-oriented response, and maintaining self-esteem, primarily because they attribute failure to a lack of effort rather than a lack of intellectual ability. This paper introduces self-theories research, and relates this research to several issues in CS Education. We then make suggestions for how CS educators can consider self-theories in their teaching and research.

Categories and Subject Descriptors

K.3.2 [**Computers & Education**]: Computer & Information Science Education—*Computer Science Education*

General Terms

Human Factors

Keywords

CS1, CS Ed research, self-theories, theories of intelligence

1. INTRODUCTION

What role do students' beliefs about themselves, particularly beliefs about their own intelligence, play in their success at learning to program or choice to major in computer science? Many psychological studies suggest such beliefs, known as *self-theories*, have a significant influence on academic success (see [7] for an overview). This paper argues that their influence may be particularly important in computer science (CS) and suggests ways CS educators and education researchers might apply these theories in their teaching and research.

Psychologist Carol Dweck and her colleagues maintain that, to varying degrees, most people's beliefs lean toward one of two theories: they either view intelligence as static (*fixed mindset*) or they perceive that intelligence is malleable (*growth mindset*). People with a fixed mindset believe you are born with a certain amount of intelligence and there is very little you can do to change it. While those with a growth mindset believe that with hard work and persistence one's intelligence can increase.

In her book *Self-Theories: Their role in motivation, personality and development* [7], Dweck reviews over two decades of psychological research, conducted by herself and others, that investigates the repercussions of holding one mindset or the other. Results show that people with fixed views are more likely to exhibit a *helpless response* to substantial challenges. While those with a growth mindset welcome challenges, viewing them as learning opportunities, and displaying what Dweck calls a *mastery-oriented response* [8]. Consequently, the achievement goals sought by these two groups also differ. Those with fixed beliefs seek *performance goals* by choosing tasks that are not overly difficult, since their primary objective is to demonstrate their ability; while those with growth views seek out challenges and adopt *learning goals* without fear of making mistakes [20].

Over the years, although unaware of the underlying theories, we have observed evidence of fixed and growth mindsets in our own classes. Two recent CS1 students, Joe and Amanda (not their real names), are classic examples.

Joe was easily frustrated by the error messages and incorrect output endemic to traditional CS1 programming. Despite extra help from his instructor and the lab assistant, when errors persisted, Joe became almost angry, his face turning red and his jaw tightening. During in-class pair exercises, he was uncomfortable when he did not immediately know how to solve a problem. If paired with a higher ability student, he was content to let his partner do most of the work. His objective was to complete the exercises, even if it meant he learned little in the process.

Expectations were high for Amanda, the younger sister of a successful CS major, when she enrolled in CS1, but she struggled with early lab assignments and answered nearly half the questions incorrectly on her first quiz. Given this dismal performance, one would expect, almost hope, she would drop the class. Instead, she dug in her heels. She

ITiCSE '08 June 30–July 2, 2008, Madrid, Spain.

consistently completed the reading assignments, began the homework the day it was posted and emailed her instructor with questions. When error messages scrolled across her screen she calmly and deliberately debugged each one, often with a smile on her face. She graciously accepted help when she was struggling and became study partners with a more advanced student who enjoyed helping her classmates.

Why do students such as Amanda work harder following setbacks, take bugs in stride, and easily give and receive help from their peers? Why do those resembling Joe quickly become frustrated and give up, often without accepting offers of help? With much effort (and in Joe's case stress and anxiety) Joe and Amanda both passed CS1. However, the quality of their learning experiences, and of their instructor's experience teaching them, was remarkably different. Realizing such differences may well stem from students' theories of intelligence was a real "Aha!" moment for us.

Not only does research on self-theories offer a viable explanation for Joe and Amanda, the most exciting results show that theories of intelligence can be changed, at least temporarily, and through a continued and compelling message, may be alterable in the long term [3]. Particularly relevant for CS are interventions which have decreased the mathematics gender gap for middle school girls [5] and diminished susceptibility to stereotype threat and improved academic performance for African American college students [3].

Although theories of intelligence are relevant in any discipline, difficulties inherent in learning to program and cultural views of computer science suggest self-theories may be even more important for CS. The next section discusses how research on self-theories and findings from CS education research support this position. It is followed by a discussion of teaching implications and recommendations for future research to investigate this assertion.

2. ARE SELF-THEORIES RELEVANT IN COMPUTER SCIENCE EDUCATION?

In this section, we examine how the concept of self-theories interacts with several issues in CS Education.

2.1 Learning to program

Despite considerable debate over the relationship of programming to CS education (e.g., [13]), most CS students begin their studies by taking an introductory programming course. These students face many challenges and a barrage of negative feedback: unfamiliar tools and environments, cryptic syntax and runtime error messages, and incorrect output caused by elusive logic errors. While students with a growth mindset view errors and obstacles as opportunities for learning, those with a fixed mindset are likely to interpret excessive negative feedback a as a challenge to their intelligence and to avoid similar situations in the future [7].

An early investigation of novices [19] described strikingly similar behaviors: it depicted *stoppers*, who "appear to abandon all hope of solving the problem on their own" (p265), harboring fear of the machine and doubt in their abilities, which "become a threat to self-esteem and one's standing with peers and teachers." (p267) On the other hand, *movers* proceed by modifying their code continuously with some success, although *extreme movers* make so many changes so impulsively as to become ineffective and "in [their] own way, disengaging from the problem." (p267) The study also linked behaviors of movers and stoppers with students' attitudes toward making mistakes: "Some novices seem to take the inevitable occurrence of bugs in stride, while others become frustrated every time they encounter a problem." (p267)

Similar risk avoidance and strategy abandonment have been linked with a fixed mindset in studies with school children [8]. One also found that, in the face of failure, 80% of mastery-oriented children maintained their problem-solving abilities and over 25% even improved, teaching "themselves new, more sophisticated hypothesis-testing strategies."(p258)

These results suggest it is worth investigating whether the ability to cope effectively with programming challenges, or the tendency to exhibit a helpless response to such obstacles, is correlated with intelligence theories. If they are, then interventions designed to encourage students toward a more malleable mindset may help improve CS1 performance and positively influence retention in CS.

2.2 Female enrollment in CS

To compound the difficulties of learning to program, cultural views reinforce a fixed view of intelligence by supporting beliefs that one only "belongs" in a course or discipline if he or she possesses an innate ability (i.e., "a gift") and when learning is effortless. Such views are especially discouraging for women students[16], who often enter introductory CS classes with less computer-related experience than men. Consequently, they may have to work harder to succeed at first, and even when high marks are achieved, the fact that they needed to work so hard to attain them can diminish their sense of accomplishment.

Research investigating female students in a pre-med calculus course (see [6] for a discussion) found that viewing mathematical ability as a gift "not only can make women vulnerable to declining performance, but it can also make them susceptible to stereotypes, so that when they enter an environment that denigrates their gift, they may lose the desire to carry on in that field." (p50) On the other hand, if you believe "ability can be cultivated through your efforts, then the stereotype is less credible." (p50)

Research has also shown that, although high-IQ girls tend to out perform all other groups in elementary school, they are also more likely to have a fixed mindset. As a consequence, they are less inclined to seek out challenges [7]. Research investigating fifth graders' ability to cope with confusion (discussed in [6]) reveals additional gender-related concerns. When presented with confusing material at the outset of learning a new task, "bright girls did not cope well. In fact, the higher the girl's IQ, the worse she did. This did not happen to boys. For them, the higher their IQ, the better they learned. The confusion only energized them." (p47)

Not surprisingly, the transition to middle school is more difficult for students who believe intelligence is fixed [5]. They are less able to adapt to increasing challenges and their math grades are more likely to decline. Negative impacts associated with fixed beliefs are in line with the tendency of fewer female high school students to enroll in Advanced Placement (AP) computer science classes. They may also be why the women students we want to attract to CS classes in college tend to avoid them.

Investigations into students' perceptions of the malleability, or innateness, of CS ability, and whether these views differ for male and female students, could shed light on the

CS gender gap. One would expect students who think CS ability is innate to base their choice to study CS on whether or not they believe they possess this so-called "geek gene".

2.3 Collaborative work

Collaborative work, and pair-programming in particular, offers a promising approach to attracting a more diverse group of students to CS. Pair-programming has been shown to boost confidence, improve retention, increase program quality and heighten students' enjoyment [17]. Students with a growth mindset "feel good about their abilities when they help their peers learn" [7, p42]. However, because those with a fixed mindset feel smartest when they out perform others, they are less likely to value collaborative learning [7].

A study assessing the self-theories of engineering undergraduates [2] found correlations between students' growth tendencies and positive beliefs in both group work and the value of creative potential in an engineering context. This suggests theories of intelligence are important for students' development in professional practice skills (outlined in [1]) which include teamwork, innovation and creativity.

It is worth investigating the apparent contradiction between findings from computer science education that suggest pair-programming can help retain women in the major [17] with those from self-theories research that show high-IQ girls are more inclined toward a fixed mindset and that those with fixed views have less interest in collaborative learning[7].

2.4 Defensive classroom climate

Defensive patterns of classroom communication mirror behaviors of a fixed mindset. Those who believe intelligence is fixed seek validation and judge and label others [7]. Such practices are exhibited in CS by students who ask "pseudo-questions" so they can demonstrate their programming knowledge, and by instructors who accord special status to students with previous experience [10]. These sorts of behaviors "can contribute to difficulties in both the recruitment and retention of women in CS [. . .] compounding women's sense of isolation and/or outsider status in a major where they comprise only about a quarter of the students" [10, p15].

Examining classroom discourse through the lens of self-theories could reveal helpful insights for decreasing defensiveness and improving support for women and other underrepresented students in CS.

2.5 Psychological success factors

CS education researchers have studied a number of psychological factors that may be related to success in introductory CS. Wiedenbeck [22] observed that *self-efficacy*, an individual's judgment of their ability to perform a task within a domain, was positively correlated to performance. She also noted that "Individuals with high self-efficacy believe that they can succeed in challenging tasks. Accordingly, they are motivated to attempt such tasks, and they apply their best efforts to achieve them." [22, p14] A study by Bergin and Reilly [4] looked at both self-efficacy and motivation and observed that intrinsic motivation had a strong correlation with programming performance, as did self-efficacy. They did not, however, establish the nature of this link.

Self-theories research, which has linked theories of intelligence to motivation and self-esteem [7], may shed light on results from CS education. Findings suggest that learners with a fixed mindset are motivated by performance goals and maintain their self-esteem by appearing smart. Some even go so far as to withhold effort in the face of a difficult task, known as *self-handicapping*, to preserve the belief that they *could* have done well had they chosen to participate [7].

3. TEACHING IMPLICATIONS—MOVING TOWARD MALLEABILITY

The previous section indicates that many current issues in CS education could helpfully be considered in light of self-theories research. It suggests that CS teachers should: "1) appreciate the significance of self-theories for student learning; 2) be able to infer whether students are inclined towards fixedness or malleability; and 3) possess strategies for encouraging 'fixed' students to move towards malleability." [23, p29] In this section we present a model for helping students adopt a malleable view of intelligence. It is based on differences in how students with fixed and growth mindsets tend to react to the difficulty of what is to be learned.

Psychologist Lev Vygotsky argued that learning is most effective when tasks are slightly more difficult than students can accomplish on their own but that can be achieved with *scaffolding*, or targeted help and guidance, from a teacher or a peer. In other words, students learn best when pushed slightly beyond their independent capabilities into what Vygotsky called the *zone of proximal development (ZPD)* [21]. Working within the ZPD is most effective when the teacher and the student have a malleable view of intelligence [23]; when both are inclined to believe in the student's capacity to develop and when the student is likely to accept scaffolding from a teacher who is willing to provide it.

Figure 1 shows the shifts required to move fixed inclinations toward malleability. Along the top we see how a student with a fixed mindset reacts to known tasks that can already be done or understood, to attainable tasks within the ZPD, and to unattainable tasks that currently cannot be understood. Along the bottom, we see how responses linked with a growth mindset differ. The following considers how a teacher can facilitate malleability within each of these zones.

3.1 A malleable view of known tasks

At times focusing on what students can already do is appropriate; exams and quizzes assess how well teachers are teaching and students are learning. Furthermore, focusing on what is known does not necessarily mean highlighting that which is easy. In fact, students with a fixed mindset feel smartest when they accomplish difficult tasks, particularly if they do so quickly or the tasks are too challenging for their peers [7]. Students with a growth mindset respond well to performance tasks when their purpose is explicit and they are not too easy. Otherwise, such tasks are likely to be perceived as a waste of time since no learning has occurred.

A technique that may help is to focus on learning goals whenever possible. For example, instead of prefacing goal statements with "To be able to . . . " or "To demonstrate skill at . . . " use "To learn how to . . . " or "To practice . . . ". Studies investigating the effects of goal orientations in a difficult college chemistry course [11] found that students who agreed more strongly with learning goals (e.g., "In my classes I focus on developing my abilities and acquiring new ones.") and less with ability goals (e.g., "In school I am focused on demonstrating my intellectual ability.") were more likely to engage in deep processing of course material and

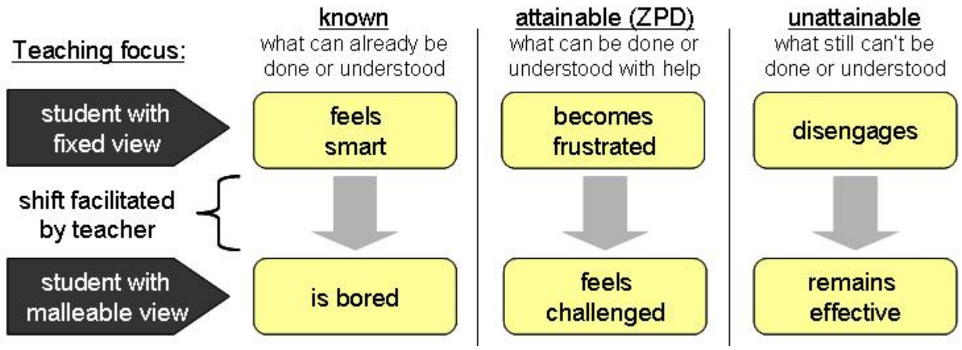

Figure 1: Moving students from a fixed to a malleable view of intelligence

had "higher intrinsic motivation, higher grades, and greater improvement over time." (p550)

Figure 1 suggests encouraging a student with a fixed mindset who feels "smart" when working on known tasks, to believe he or she should feel "bored" instead. This seems counterintuitive. However, if the objective is to encourage a malleable way of thinking, that is essentially what Dweck[7, p121] suggests:

> When a student has done something quickly, easily, and perfectly . . . we should apologize to the student for wasting his or her time with something that was not challenging enough to learn anything from.

If this is the reaction when a CS1 student easily completes a lab assignment and hops up to leave before the rest of the class, it communicates that effort is expected and that mistakes offer opportunities for learning. Hopefully that same student will be less likely to have a "meltdown" when later assignments require substantially more effort.

3.2 A malleable view of attainable tasks

Bridging the gap between what is known and what can be achieved (the ZPD) often requires a teacher to provide *scaffolding* by engaging, motivating and guiding the student. Scaffolding is more difficult when the student has a fixed view of intelligence and only feels comfortable working on tasks he or she can accomplish independently. To make matters worse, when faced with setbacks, students with a fixed mindset are less likely to accept offers of help [14].

Psychology research suggests students' abilities to cope with challenging tasks such as debugging could be improved by altering how bugs are presented; shifting students' view of them from something only to be avoided into opportunities for learning. Research with fifth-graders asked to perform a pattern recognition task [9, p7] compared those told "although you won't learn new things, it will really show me what kids can do" to those told "you'll probably make a bunch of mistakes, get a little confused, maybe feel a little dumb at times—but eventually you'll learn some useful things." When the first group also believed their skill at the task was low they exhibited a helpless response; they blamed mistakes on lack of ability and gave up seeking effective ways to overcome them. In contrast, the second group, whether they thought their ability was high or low, responded in a mastery-oriented manner; they sought more challenging tasks and used more sophisticated strategies.

Another way to encourage a mastery-response to challenges is to praise students for their effort rather than for their ability or intelligence. In [18], fifth-graders were told they had correctly solved at least 80% of a set of matrix problems. Half the students were then also told "You must be smart at these problems" while the others were given the feedback "You must have worked hard on these problems." After failure on a subsequent task, those praised for intelligence were less persistent, performed worse and enjoyed the task less than those praised for effort.

3.3 A malleable view of unattainable tasks

Diverse student backgrounds and abilities make it nearly impossible to write assignments within the ZPD for all students in a class. This means some students will inevitably have to cope with seemingly impossible tasks.

Students with a growth mindset cope more effectively than those who have a fixed view because they attribute their difficulties to causes within their influence and maintain their focus on learning while continuing to apply effective strategies [7]. We can help "fixed" students by focusing on productive attributions for failure such as inappropriate strategies, poor planning or lack of effort (i.e., factors within the student's control).

Occasionally, teachers may give an assignment that is beyond the capabilities of most students in a class. It may be important to acknowledge when this has happened so students with fixed views will be less likely to blame themselves for failures. Negative effects may be mitigated by providing additional scaffolding, modeling effective strategies, and emphasizing what can be learned from the assignment.

3.4 What about teachers' theories?

Teachers' beliefs are also important to the educational process [23]. People who think intelligence is malleable are more likely to help others [7], and personnel management research [20] has shown that managers with growth views receive better evaluations on the quantity and quality of their employee coaching.

A study of CS instructors' perceptions of student difficulties revealed that, for some students, success stems from an inexplicable, intrinsic ability—they just "get it" [15]. This is natural given variations in students' backgrounds and low success rates in many introductory classes. However, teachers' beliefs about the malleability of students' abilities can have an influence on student success [23]. This suggests we should cultivate malleable views in ourselves by rejecting the idea that success at CS is caused by some magical, intrinsic ability and resisting the temptation to quickly judge which students are likely to succeed and which are not.

4. CONCLUSIONS AND FUTURE WORK

The previous discussion suggests that interventions designed to encourage malleable views of intelligence may help CS students become more resilient, willing to take risks, and appreciative of group work.

The self-theory tendencies of CS students [1] should be investigated and the effects of self-theories on student learning and success assessed. Reading passages [14], workshops [5, 12] and even a pen pal project [3] have been used to positively alter the self-theories of adolescents [5], university students [3, 14] and managers [12]. The potential of similar self-theory interventions in CS should also be explored.

Examining the role of self-theories in CS offers a range of research possibilities: from large-scale, quantitative assessments of CS students' self-theories; to rich, qualitative investigations of relationships between theories of intelligence and behaviors or attitudes; to a new lens for evaluating a classroom intervention or pedagogical trend. Each presents an opportunity to better understand, and perhaps improve, the teaching and learning of computer science.

Currently the authors are working with other researchers to investigate whether a "Saying is Believing" [3] intervention can encourage CS1 students to have a growth mindset.

5. ACKNOWLEDGMENTS

We are grateful to Allen Olsen of Evergreen State College for his guidance in the study of how people learn, to Michele Folsom and Renée McCauley for their helpful feedback, and to the rest of the DEBUG group for inspiration and suggestions. This work was partially supported by a grant from the National Science Foundation (DUE-0647688).

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