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Modeling the relation between students' implicit beliefs about their abilities and their educational STEM choices

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Abstract Despite the large body of research on students' educational and career choices in the field of technology, design, and science, we still lack a clear understanding of how to stimulate more students to opt for a study path or career within the STEM fields (Science, Technology, Engineering, Mathematics). In this article, we outline a new theoretical framework to describe how students' implicit belief about the malleability of their intelligence can be an important precursor of their STEM educational and career choice behavior. Based on the different bodies of literature about STEM choices and about students' implicit beliefs about their abilities, we present three hypothetical pathways, in the form of testable models, that describe potential relations between the implicit theories that students may hold regarding the malleability of their STEM ability and students' intentions to pursue a STEM career. Each pathway outlines a specific mediating factor influencing this relation: (a) self-efficacy beliefs, (b) stereotypical thinking, and (c) motivational beliefs. These pathways provide more insight into the underlying mechanisms that may affect STEM choice behavior. In our view, such a theoretical underpinning is a necessary prerequisite for further scientific investigation into the potential relations between students' implicit beliefs about their potential development, relevant psychological variables, and STEM choice behavior. Furthermore, we believe it provides a theoretical foundation for practical interventions that aim to stimulate STEM choice behavior.

Keywords Implicit theories of intelligence · Mindset · STEM · Ability related beliefs · Educational and career choice · STEM pipeline

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Introduction

There is a growing need for science, technology and design oriented and educated workers in order to ensure technological innovation and economic growth. This need is present on every occupational level, from academic researchers to hands-on vocational graduates (Osborne and Dillon 2008). However, many Western countries are faced with a lack of students in the so-called STEM field, i.e., the field of science, technology, engineering, and mathematics, including technology and design. Although the STEM-field is broad, and not all disciplines in the STEM-field are confronted with a lack of enrolment to the same extent, it certainly does apply to engineering, physics, and mathematics studies (Bøe et al. 2011; U.S. Congress Joint Economic Committee 2012). In addition, especially the underrepresentation of women and ethnic minorities in these fields is cause for concern (National Science Foundation 2013; OECD 2008; Watt et al. 2012).

The lack of interest of secondary and high school students in STEM-related studies and work fields is a complex problem and the reasons for the shortage of STEM-skilled workers are manifold and have been studied from different perspectives, i.e. from cultural, sociological, educational, and psychological perspectives (for a literature overview, see: Van Tuijl and Walma van der Molen 2016). One category of factors that is often referenced as being particularly salient are psychological factors, such as negative attitudes, self-efficacy beliefs, stereotypical beliefs, and motivation. The body of experimental literature on STEM choice behavior often regards these factors as points of departure for understanding choice behavior. However, these psychological factors are subject to change themselves and may be influenced by experience, social environment, and implicit beliefs. Moreover, a large body of cognitive and neuro-scientific research indicates that, to a large extent, decision-making processes are implicit and unconscious (for example work by Kahneman and Tversky 1979; Wolford et al. 2000). Decisions, such as for a STEM career, may depend on many implicit motivations, attitudes, heuristics, and personal theories (Bechara et al. 2000; Kahneman and Tversky 1979). Individuals therefore tend to seek post hoc, explicit, and concrete explanations for the choices they have made. This implies that many of the more explicit explanations for STEM choice behavior may be post hoc explanations of choices that are influenced by implicit factors. In our view, it is therefore important that research into STEM educational and choice processes takes into account the *preceding* implicit factors that may influence the more overt psychological factors such as self-efficacy, stereotypical beliefs, and motivation. Such a research angle may provide more insight into the potential mechanisms underlying STEM educational and career choices and may provide alternative, more efficient approaches for interventions targeting STEM choice processes.

One implicit factor that has repeatedly been suggested to have impact on the above-mentioned psychological factors is the implicit theory of intelligence, i.e. a student's implicit beliefs about the malleability of his/her own intelligence. Over the years, different researchers have presented the idea that implicit theories of intelligence might influence STEM career choices (Blackwell et al. 2007; Burkley et al. 2010; Dweck 2006, 2008; Murphy and Thomas 2008; Nix et al. 2015; Wang and Degol 2013). A recent study by Nix et al. (2015) relates students' *perceived mathematical ability under challenge* to educational STEM choice behavior, such as completion of highest science coursework in high school, retention in intended STEM majors and major type. Perceived mathematical ability under challenge refers to the implicit theories of students as well as to their self-efficacy beliefs regarding mathematics. The study by Nix et al. provides the first, and until now, only empirical support for the hypothesis that implicit theories may influence STEM choice behavior. However, the underlying mechanisms by which perceived abilities influence STEM choice behavior are not explained in the study nor in the other studies that postulated hypotheses about the potential influence of implicit theories, which leaves the underlying mechanisms unclear.

In order to be able to experimentally investigate the potential (in)direct effects of students' implicit beliefs on their STEM choice behavior, it is necessary to gain more insight into the potential underlying relations between implicit beliefs and STEM choice behavior. As stated before, there are many psychological factors that might contribute or play a role in this relation and these psychological variables might, in turn, be subject to students' implicit belief system. Dweck's self-theories meaning system, i.e. the framework for understanding achievement in light of these implicit beliefs (Dweck 2000) is complex; incorporating a multitude of concepts including self-efficacy, negative and positive effort beliefs, achievement and performance goals, stereotypical beliefs, and attributions and strategies in response to failure. The underlying relations and interactions between these concepts have been the focus of investigation in many studies (see Burnette et al. 2013 for an overview; Renaud-Dubé et al. 2015; Tempelaar et al. 2015) and are still a subject of discussion. In our view, if we want to enhance progress in the scientific investigation of STEM choice-processes and improve the effectiveness of interventions aiming to stimulate STEM choices, we need a better understanding of how the meaning system of implicit self-theories relates to STEM educational and career choice processes.

To that end, the goal of the current article is to provide a comprehensive theoretical overview of the potential mechanisms by which implicit beliefs may affect STEM choice behavior, and how different mediating factors might influence or contribute to this relation. Until now, no testable hypotheses or models describing these potential relations have been suggested, which makes it difficult to empirically investigate the role of this meaning system in STEM choice processes or to interpret research findings, such as by Nix et al. (2015). Furthermore, students' implicit beliefs about their intelligence have been shown to be malleable through interventions (e.g. Blackwell et al. 2007). When implicit beliefs do influence STEM choice behavior, as hypothesized in the current article, then changing these implicit beliefs might be a very concrete and practical approach for schools to stimulate their students' STEM choices. Providing students with insights into the mechanisms by which implicit beliefs may influence their STEM choices could enhance the effect of such interventions even further.

Thus, in the current theoretical article, we present a first and necessary step to boost progress in this field of research by providing simple and testable models, based on an integration of earlier research, that describe the mechanisms through which implicit beliefs about the malleability of one's intelligence may influence STEM choices. We reviewed and analyzed the body of literature on implicit theories of intelligence on the one hand and STEM educational and career choice processes on the other to search for empirically supported relations between the different concepts of the meaning system and STEM choice processes. From these relations, we identified three testable models, or *pathways of influence*, which describe how implicit theories of intelligence may exert their effect on STEM choices. Again, it should be noted that the current theoretical endeavor is a necessary prerequisite for the development of meaningful experimental designs and the interpretation of experimental findings in the complex context of psychological factors affecting STEM choice behavior. Of course, the next step will be to provide empirical data testing these hypotheses. The current article, however, solely presents the theoretical framework, since it encompasses an elaborate review of the literature and detailed argumentation of the different relations, which would not fit an empirical paper.

The implicit theory of intelligence perspective

Students often hold negative attitudes toward technology and design, science, and mathematic subjects (e.g., Barmby et al. 2008; Francis and Greer 1999). These negative attitudes manifest themselves by a variety of observations that show that many students regard STEM related school subjects as difficult and boring (Jones et al. 2000; Watt 2004) and believe it takes more effort to successfully complete these subjects than other school subjects, they see it as a difficult challenge (Watt 2004). These negative attitudes already arise at the elementary school level, where most teachers are not trained properly to teach STEM topics or design education or hold a negative attitude towards STEM subjects themselves (Andre et al. 1999; Tai et al. 2006; Turner and Ireson 2010; van Aalderen-Smeets et al. 2012; van Aalderen-Smeets and Walma van der Molen 2015). In addition, these negative attitudes may become more negative with age (Barmby et al. 2008; Francis and Greer 1999; Watt 2004) and may play an enduring role during students' entire school career (see Osborne et al. 2003 for a review of research on students' attitudes towards science and technology). However, different students cope differently with the perceived challenge posed by STEM subjects. Some students do not cope well and become demotivated to pursue a STEM study path. Others, who often perceive STEM to be equally complex and difficult, do not seem to be thrown off by the challenge they are faced with. They put effort into learning these subjects, in overcoming potential difficulties and will be more likely to choose a STEM oriented study path compared to the first group of students. What accounts for these differences in students' approaches to avoid or overcome the difficulties and challenges of STEM education? Why do some students welcome the challenge, while others, who may show equal ability, are thrown back by it?

Carol Dweck and colleagues (e.g., Dweck 2000; Dweck and Leggett 1988; Dweck and Sorich 1999; Henderson and Dweck 1990) postulate that the underlying core beliefs that account for this difference in 'personal qualities' that shape a student's response to challenge are the implicit theories that students hold regarding the malleability of their own intelligence. Implicit theories refer to beliefs that are not explicitly articulated in a person's mind, but that form a schematic knowledge structure that guides a person's perceived beliefs about his or her abilities, independent from their actual intellectual ability. The core implicit beliefs described by Dweck's motivational model can be divided into two categories: entity and incremental theories. Students holding an implicit *entity* theory believe that intelligence (i.e., a set of abilities and capabilities in a given area) is a fixed and unchangeable entity; they implicitly believe that they are born with a certain amount of ability in a given area and cannot do much to develop this. According to Dweck (2000), students holding entity beliefs set goals that are focused on external performance criteria and on showing their ability to others, they easily loose self-confidence in case of failure, they give up more easily, and they are more prone to maladaptive strategies, such as avoidance and withholding effort. Furthermore, on a neuronal level, students holding an entity mindset orient differently towards negative performance: they show less sustained memory-related activity to the content of feedback and they show reduced effortful encoding of the feedback information, meaning that they process the information needed to improve their performance not as effectively as those holding incremental beliefs (Mangels et al. 2006).

On the other hand, students holding an implicit *incremental* theory do recognize the influence of aptitude, but think of intelligence, or their abilities in a given area, as a quality that can be developed within the scope of their aptitude. These students show a mastery-oriented response in case of failure, meaning that they focus on the constructive elements of the feedback that they obtain, intend to put more effort into the difficult task, adopt more positive strategies, and are less prone to doubting their own abilities. These differences in students' responses are believed to surface predominantly in case of challenges, setbacks, or perceived failure (Burnette et al. 2013; Dweck 2000), but the implicit theories themselves are believed to be already present and developed from an early age on. The perceived setbacks or failures can be very explicit, for example in the case of failing important tests, or they can be rather small, like not being able to make a homework assignment or getting negative criticism from a teacher.

In the present article, we hypothesize that those students who regard STEM subjects as complex and something you need to put a lot of effort into (negative attitude) and who, in addition, hold an entity theory of intelligence, are especially at risk of 'leaking out of the STEM pipeline'. We argue that this combination of beliefs may play a key role in students' STEM field performance, in their willingness to take a risk within the STEM field, and subsequently to pursue a STEM oriented high school profile, future education, or STEM profession.

The malleability of students' implicit theories of intelligence

In our view, an important reason to investigate the possible influence of students' implicit beliefs about the malleability of their capacities, especially in the field of STEM educational and career choices, is that these beliefs are malleable themselves. Research has shown repeatedly that schools, teachers, parents, or researchers can influence and stimulate the growth of children's incremental beliefs, by means of both large and small-scale interventions (Aronson et al. 2002; Blackwell et al. 2007; Burke and Williams 2012; Dommett et al. 2013; Dweck 2000; Good et al. 2003; Paunesku et al. 2015; Schroder et al. 2014). An influential article by Blackwell et al. (2007) showed that a large-scale intervention amongst 7th grade students improved their beliefs about incremental intelligence, resulting in increased math performance and motivation over a period of a year. The intervention included information about brain plasticity, i.e. the neural mechanism that underlies learning and the manner in which connections between neurons in networks change under influence of experience, and information about implicit theories of intelligence and the beneficial effects of an incremental theory on intelligence. Also, Dommett et al. (2013) showed that workshops on neuroscience and brain plasticity increased the beliefs of 11 and 12-year-old students in incremental intelligence, which lasted over 20 months.

But not only neuro-education may improve students' implicit theories. Burke and Williams (2012) showed that a thinking skills intervention improved students' incremental beliefs about their intelligence. In addition, small-scale interventions also showed changes in mindsets. Schroder et al. (2014) showed that inducing incremental or entity beliefs by having participants reading either an incremental or entity belief-stimulating article, had effects on attentional processes related to cognitive control. Paunesku et al. (2015) delivered small-scale interventions to students stimulating growth mindsets (i.e. incremental theories) through online-modules and showed positive effects on grade-point averages. The above-mentioned studies investigated the effects of one-time interventions. Continuous attention to stimulating an incremental mindset in schools might sort even longer-term effects.

In addition, research has shown that parents and teachers may directly influence students' implicit theories of intelligence. Good et al. (2003) showed that if teachers explicitly provide incremental-based support (such as encouraging students to view intelligence as malleable and to attribute academic difficulties to the novelty of the educational setting) students' implicit theories and achievement were positively influenced. But even if teachers' and parents' support does not explicitly refer to incremental beliefs, their feedback may have a large effect on students' implicit theories and achievement. Each day, students and children receive positive compliments from their parents and teachers in order to reinforce motivation and self-confidence. The object of these compliments, whether they are aimed at the characteristics of the person or aimed at the process, has a major influence on children's' implicit theories (Brummelman et al. 2014; Mueller and Dweck 1998; Pomerantz and Kempner 2013). Compliments that stress the performance and person ("you are smart") encourage an entity theory, while compliments that focus on the process ("you tried your best" or "you worked very hard") stimulate an incremental theory about intelligence (Pomerantz and Kempner 2013). In addition, the more inflated the compliments are ("you are incredibly smart"), the more contradictory the effect seems to be on children with low self-esteem. Brummelman et al. (2014) found that inflated compliments decreased challenge-seeking behavior and increased avoidance of crucial learning experiences in children with lower self-esteem. These results suggest that the tendency of many teachers and parents to compliment children having low-esteem with inflated praise may actually backfire; it can decrease their self-esteem even more. On the other hand, inflated praise was found to have an opposite effect on children with high self-esteem: it increased their challenge seeking behavior and their positive exploration of learning experiences (Brummelman et al. 2014). These studies show that implicit theories can be changed through interventions directed at students or through the feedback of teachers and parents, and that a change towards incremental theories has a positive effect on self-efficacy and achievement. This suggests, in case implicit beliefs indeed influence STEM choice processes, that stimulating incremental beliefs in students might positive stimulate them towards a STEM oriented educational or career choice.

Three pathways of influence

We hypothesize that the relation between implicit theories of intelligence and STEM educational and career choices is indirect, meaning that one's implicit theory does not influence the choice for a STEM study path directly, but that it exerts its effect through mediating or moderating factors. Reviewing the relation between implicit theories of intelligence and psychological factors such as self-efficacy or motivation on the one hand and between these psychological factors and educational or career choice on the other hand, has led us to propose three potential *pathways of influence,* see Fig. 1. These pathways are intended as testable models to investigate the relation between implicit theories and STEM choice behavior. Since we are only starting to investigate these relations, we believe it is better to start with solid, separate, and simple models that generate understandable interpretations, rather than formulating a comprehensive theory that is difficult to test empirically and that therefore might not easily lead to practical tips and

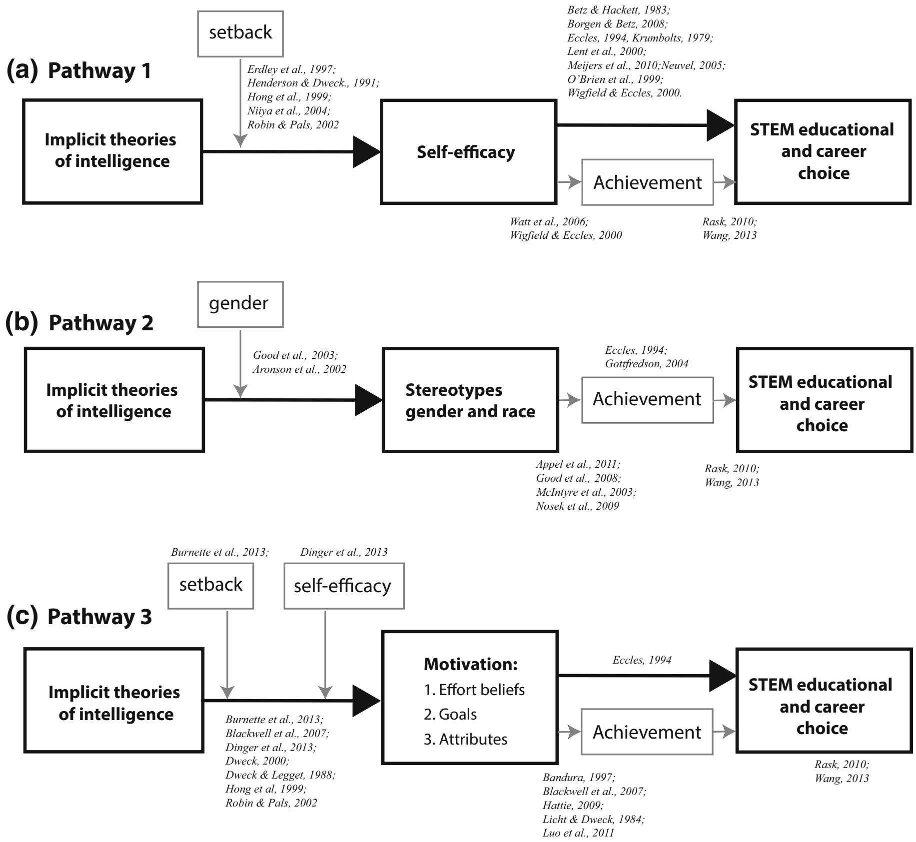

Fig. 1 Testable models of the three hypothesized pathways of the influence of implicit theories of intelligence on STEM educational and career choices, mediated through **a** self-efficacy beliefs, **b** stereotypical thinking, and **c** motivational beliefs

interventions for schools. Important to note is that by presenting the three pathways separately we do not claim that they are independent. On the contrary, we do recognize that in reality there are probably many interrelations and interactions between the variables that guide choice behavior. However, the goal of the current article is not to present a proven model of the relations between implicit theories of intelligence and STEM choice behavior, including the mutual relations between all related factors, or a comprehensive theory of STEM choice behavior in general, but to provide a theoretical basis for further empirical research and thinking about the role of implicit theories in the STEM field. The pathways are presented in a more or less arbitrary order that does not necessarily imply the salience, strength, or importance of one pathway compared to another.

Pathway 1: influence of implicit theories through STEM related self-efficacy

The first pathway, or model, depicted in Fig. 1a, shows a relation between implicit theories of intelligence and educational and career choice processes, mediated through self-efficacy beliefs. The concept of self-efficacy was first postulated by Bandura's social cognitive theory (Bandura 1997) and refers to the perceived ability of an individual to perform a particular behavior that may contain difficult and stressful elements, e.g., students' perceived ability for school mathematics, science, or physics. The relation between implicit theories and self-efficacy might seem counterintuitive. At first sight, it might seem logical that high-achievers, holding positive self-efficacy beliefs, are more likely to have an incremental mindset, while those that have low self-esteem might be more likely to hold entity beliefs. However, several studies investigating this relation showed that this is not the case; self-efficacy does not correlate with either an entity or incremental belief, nor do high self-efficacy beliefs (i.e., high self-esteem) prevent a person from making a helpless response or a negative attribution in case of a setback (Erdley et al. 1997; Hong et al. 1999). This can be explained by taking into account the context or the situation; as long as there is no perceived challenge or setback, the maladaptive response of the entity theorist does not occur and achievement outcomes are predicted by self-confidence (MacGyvers 1992 in Hong et al. 1999). However, students holding an entity theory will more likely attribute a setback or failure to a lack of their ability, thereby decreasing their self-efficacy beliefs when encountering difficulty, while incremental theorists are more likely to attribute their failure to a lack of effort and thereby preserve their self-efficacy beliefs (Erdley et al. 1997; Henderson and Dweck 1990; Hong et al. 1999; Niiya et al. 2004). Entity theorists' self-confidence is contingent on external validation because the source of their self-confidence is success, as a proof of their ability (Crocker and Wolfe 2001; Dweck 2000). A longitudinal study shows the ecological validity of this relation; Robins and Pals (2002) observed that students with an entity orientation were more likely to decline in self-efficacy over the four years of college compared to students holding incremental beliefs. This was independent from their average level of self-efficacy over their college years. The authors explain their findings by highlighting the increased number of academic challenges in college, which is accompanied by a heightened threat of failure. This triggers the maladaptive response of entity theorists regarding self-efficacy. Self-efficacy beliefs are thus vulnerable in students with entity beliefs, independent of the initial self-efficacy beliefs before a perceived setback or challenge has occurred. We therefore hypothesize that setbacks moderate the relation between entity beliefs and self-efficacy, see Fig. 1a.

Research has shown that self-efficacy beliefs play a major role in STEM educational and career processes and this has been investigated foremost in the math domain. It has been shown that math related self-efficacy beliefs are correlated with the extent to which students choose science-based college majors, independent of actual math performance (Betz and Hackett 1983) and that self-efficacy beliefs predict science and mathematics vocational interest (O'Brien et al. 1999). Moreover, extensive research by Eccles and colleagues has shown that ability beliefs and expectancy for success play a major role in STEM related educational and career choice processes (e.g., Eccles 1994; Wigfield and Eccles 2000). Self-efficacy is also a salient concept in non-STEM educational and career choice research. Many general career choice theories, such as the Social Cognitive Career Theory (Lent et al. 1994, 2008), or the Theory of Circumscription and Compromise (Gottfredson 1996, 2004) include self-efficacy as a predictor for educational and career choices. In addition, self-efficacy also fits in with the so called 'garbage-can model' of career choice, which states that many students make a 'negative' choice by excluding options based on perceived barriers and than opt for the option that is left over. One of the perceived barriers that may contribute to an exclusion of certain vocational or educational options is the presence of low self-efficacy beliefs (Borgen and Betz 2008; Meijers et al. 2006).

Achievement related choice

As an alternative to a direct route between self-efficacy beliefs and STEM educational choice, the relation could be mediated by achievement (Fig. 1a). Self-efficacy has been found to predict achievement, in more general and in STEM related areas, which in turn influences STEM educational and career choice (e.g., Watt et al. 2006; Wigfield and Eccles 2000). In addition, there is an intuitive relation between achievement in a certain subject and choice behavior, which is supported by research that shows that high school math achievement and absolute and relative grades influence STEM oriented educational choices (Rask 2010; Wang 2012). In essence, we can assume that students do not make a study or career choice for a subject they perform very poorly in. However, the reverse argument is not valid: if a student performs well in a school subject, it does not predict whether he/she will make a study choice in favor of this subject, since the actual positive choice is dependent on a multitude of factors (Eccles 1994). Thus, adequate achievement can be viewed a necessary, but not a sufficient condition for educational and career choice. Watt et al. (2006) argue that even though math achievement does not explain, for example, gender differences in educational choices, it is important to take achievement measures into account as a control measure, to be able to investigate the unique effect of psychological factors such as self-efficacy over and above students' achievement scores. We therefore included achievement scores as a possible mediator between the psychological factors and STEM educational and career choices in each of the three pathways (see Fig. 1a–c).

Gender differences in STEM related self-efficacy

Self-efficacy especially seems to play a role in *femal*e STEM educational and career choice behavior. Math related self-efficacy beliefs are lower for females than for males, even though they have similar math grades and test scores, and this gap emerges at middle school and continues into college (Andre et al. 1999; Betz and Hackett 1983; Correll 2001; Else-Quest et al. 2010; Freedman-Doan et al. 2000; Nagy et al. 2008; Nix et al. 2015; Pajares 2005; Watt et al. 2006; Wigfield et al. 1996). So why do girls perceive themselves as having less talent and ability for math than boys, even though their grades and test scores are often equal? One explanation is that females, and especially bright girls, tend to have a tendency for entity beliefs regarding their intelligence and especially their mathematical ability (Dweck 2006; Nix et al. 2015). If girls are more likely to have entity beliefs than boys, we can expect that girls are more likely to have negative self-efficacy beliefs compared to boys. Take for example a smart girl with entity beliefs, who is used to successful achievement without much effort. If she is suddenly forced to put additional effort into a STEM subject, she will be more likely to perceive this need for effort as a sign of a lack of ability in this particular subject than her classmates with incremental beliefs (who, according to Dweck (2006), are more often male than female classmates). This, in turn, may trigger a maladaptive response of decreasing self-efficacy. Note that this gender difference in STEM related self-efficacy only accounts for the *number* of girls and boys with lower self-efficacy levels (more girls with an entity theory leads to more girls with low self-efficacy beliefs), and does not imply that there might be a gender-dependent difference in the *processes* that underlie the relation between implicit beliefs and self-efficacy.

Conclusion pathway 1

The findings listed above provide a plausible rationale for assuming an indirect relation between implicit theories and STEM educational and career choices mediated through self-efficacy beliefs. In this pathway, we hypothesize that students holding entity beliefs about their STEM aptitude are at risk for declines in STEM related self-efficacy when confronted with a setback, and that this decline in self-efficacy negatively affects the tendency for a STEM related educational or career choice. In addition, we assume that this indirect relation holds for male and for female students. Taken together, the reviewed studies suggest (1) that entity beliefs precede self-efficacy beliefs, (2) that self-efficacy mediates the influence of entity beliefs on STEM educational and career choices, (3) that the (subjective) experience of setbacks moderates the relation between entity beliefs and self-efficacy, and (4) that the relation between self-efficacy and STEM choice could be mediated by achievement. If this hypothesized pathway is indeed valid, it would imply that improving the implicit theories of students, and especially girls, who are thought to hold entity beliefs more often than boys do, could improve their STEM related self-efficacy beliefs and consequently would increase the probability that students will choose a STEM related study path.

Pathway 2: influence of implicit theories through stereotypical beliefs

The second pathway hypothesizes that students holding entity theories of intelligence are more susceptible to internalizing gender or racial stereotypical beliefs and that, consequently, these stereotypical beliefs negatively influence STEM educational and career choices. Catherine Good and colleagues have shown in multiple studies that implicit theories have an effect on the susceptibility for internalizing gender and race stereotypical beliefs regarding STEM aptitude and general intelligence (Aronson et al. 2002; Good et al. 2003). In the US, Afro-American college students tend to underachieve, which has instigated the stereotypical belief that their poor performance is due to their intellectual abilities. The entity belief that intelligence is given and fixed provides a fertile soil for stereotypical beliefs; "you have a certain amount of intelligence that cannot be changed and if you are an Afro-American you have less of *it* compared to non-Afro-Americans". Students holding incremental beliefs, on the other hand, are thought to be less susceptible to stereotypical beliefs; they believe they can develop their competencies and that they can overcome the alleged gender or racial disadvantages with hard work. Aronson et al. (2002) showed that improving Afro-American students' implicit theories of intelligence made these students less susceptible to stereotypical beliefs, which resulted in greater enjoyment and higher achievement in college. Similar results were obtained for female students' math scores (Good et al. 2003). Girls that gained more incremental beliefs regarding the malleability of their competencies through an intervention earned higher standardized math scores compared to those that did not improve their implicit theories. The same study showed that minority students who improved their implicit theories earned higher standardized reading scores compared to minority students who did not improve in their implicit theories (Good et al. 2003).

The body of career choice research has shown that stereotypical beliefs influence educational and career choice processes (for a review see: Hartung et al. 2005; van Tuijl and Walma van der Molen 2016). Two major theories on educational and career choice, the comprehensive Expectancy-Value theory (Eccles 1994) and the theory of Circumscription and Compromise (Gottfredson 1996, 2004), postulate that gender stereotypes are partially responsible for education and career choice selection. The Expectancy-Value theory links educational and career choices to two sets of beliefs: the individual's expectations for success and the values he or she attaches to the different options. More specifically, the theory assumes that educational and career choices are guided by self-efficacy beliefs, the relation to personal goals, gender stereotypical beliefs, and the potential cost of a certain choice. Each of these variables is influenced by experience, cultural norms, and the influence of peers, parents, and teachers. According to the theory, gender stereotypical beliefs (or perceived gender roles) influence STEM educational and career choice in several ways. For example, gender beliefs can lead to differential hierarchies of core personal values and long-term goals, such as values given to family, care giving, making money, or being successful in your occupation.

Gottfredson's theory of Circumscription and Compromise (1996, 2004) states that two distinct processes may influence career choices. The first process is called Circumscription, which is the process by which children progressively eliminate occupations for consideration because they perceive these occupations to be unacceptable for themselves. The second process is Compromise, in which children begin to relinquish the most preferred options and substitute them for more accessible ones. During the phase of circumscription, children's increased orientation to sex roles and social valuation of occupations make them eliminate a whole array of occupations because they are regarded as being too masculine or feminine or being unsuited to their non-vocational, often gender-driven goals (such as family planning, or generating sufficient financial means). But also during the phase of compromise, compatibility of children's choice of vocational training is influenced by how well they believe it matches with their gender. These stereotypical beliefs are therefore thought to contribute to the gender gap in the field of STEM education, i.e. the fact that females are less likely to pursue a STEM career or to make a STEM educational choice than males are. In our second model, gender is therefore hypothesized to moderate the relation between implicit theories and stereotypical beliefs; i.e. in the case of STEM subjects, the relation between holding an entity theory and gender stereotypical beliefs is stronger for females compared to males.

Gender differences in STEM achievement: STEM aptitude versus stereotypical beliefs

There is a controversy regarding the difference in STEM related innate abilities between girls and boys and differences in achievement. Some research provides support for the claim that this gap is due to innate sex differences in cognitive abilities underlying STEM subjects, thereby nourishing the stereotypical belief that boys have more aptitude for STEM related subjects compared to girls (e.g., see for an overview Halpern and Wright 1996). However, this claim is highly debated. For example, Spelke (2005) suggests that there are no differences in the aptitude for mathematics and science between boys and girls. There are studies that show that girls even outperform boys in both math and science courses (Duckworth and Seligman 2006). Furthermore, a meta-analysis of two large-scale international data sets (2003 TIMMS and PISA) showed that there are no mean differences in math achievement between 13 and 15 year old boys and girls (Else-Quest et al. 2010). Research suggests that in countries where differences between boys and girls in STEM performance do exist, these may be due to internalizing gender stereotypical beliefs. A large-scale international study by Nosek et al. (2009) showed that national differences in gender-stereotypical beliefs regarding science ability predicted the national gender-differences in science and mathematic achievement, indicating that the stronger the stereotypical beliefs within a country, the larger the gender gap in science and math achievement. Other research shows that stereotypical beliefs lead to declines in female achievement in STEM related subjects and skills, such as math performance and STEM related learning processes (Appel et al. 2011; Good et al. 2008). On a positive note, nullifying this stereotypical belief in females has shown to increase female achievement in these areas (Good et al. 2008; McIntyre et al. 2003). In sum, it seems safe to conclude that a large part of the gender differences in achievement in the STEM subjects can be attributed to stereotypical beliefs. We therefore assume that achievement mediates the relation between stereotypical beliefs and STEM choice behavior. A gender-stereotypical belief regarding STEM abilities is firmly interwoven in our culture and female students that hold entity theories of their intelligence seem to be more likely to be affected by these stereotypical beliefs; it supports their belief that aptitude for math and science is innate, cannot be changed, and that they have less of it because they are female. This in turn affects their achievement in STEM related subjects.

Conclusion pathway 2

The findings described above provide a plausible rationale for assuming an indirect relation between students' implicit theories about their intelligence and their STEM educational and career choices, which is mediated by their stereotypical beliefs and achievement. In the case of STEM topics, the relation between entity beliefs and gender stereotypical beliefs is expected to be stronger for female students holding an entity theory, who might internalize these stereotypical beliefs to a greater extent than male students. The influence of such stereotypical beliefs may express itself by a decreased likelihood of pursuing a STEM major or career, mediated through achievement. Taken together, the reviewed studies suggest (1) that entity beliefs influence stereotypical beliefs, (2) that stereotypical beliefs mediate the influence of entity beliefs on STEM educational and career choices, (3) that gender may moderate the relation between entity beliefs and gender stereotypical beliefs, and (4) that the relation between stereotypical beliefs and STEM choice could be mediated by achievement. If this hypothesized pathway is indeed valid, it would imply that improving the implicit theories of students, and especially those of female and minority students, would diminish their stereotypical beliefs and increase the probability that students will choose a STEM related study path.

Pathway 3: Influence of implicit theories through STEM motivation

In the third pathway, we hypothesize that implicit theories affect STEM educational and career choices through motivational beliefs. We propose that students holding entity beliefs are more at risk for a decline in motivation, which subsequently affects their propensity for a STEM educational or career choice and which may negatively affect their achievement over time. Motivation is a complex concept that has been divided into many different components by many different models and theories. The motivational framework that we use in the present article has previously been described by Blackwell et al. (2007) and consists of motivational beliefs about (a) effort, (b) goal orientation, and (c) strategies and attributions in response to failure (Blackwell et al. 2007; Jones et al. 2012). These three motivational components have been linked to implicit theories of intelligence and they will each be outlined below.

Effort beliefs

Students holding entity beliefs about their ability are less likely to be inclined to put effort into a task that they perceive as being difficult, and they value effort as being less important (Dweck 2000). In addition, these students reason that if a task demands effort they probably lack the right ability for the task; "If I had the ability, I would not have to put this amount of effort into it". Hong et al. (1999) showed that students holding incremental theories attribute their performance on a task more to effort compared to students holding an entity theory of intelligence, who attribute their performance more on innate ability.

Achievement goals

The second motivational belief refers to students' achievement goals. Achievement goals are viewed as the purpose or focus of particular competence-related behavior, such as the motivation for studying for a test. Achievement goals are generally divided into performance goals, which refer to the goal of *demonstrating* competence, and mastery goals, which refer to the goal of *developing* competence through the acquisition of new skills and knowledge (see Ames 1992, for a review). Dweck and Leggett (1988) suggested that mastery goals were more adaptive for learning compared to performance goals. Moreover they, and others, showed that incremental theorists show a focus on mastery goals, i.e. they view achievement situations as possibilities to extend their capabilities, thereby adopting a mastery goal (Dweck and Leggett 1988; Robins and Pals 2002). These students are focused on increasing their competences, they interpret negative feedback as a learning opportunity rather than proof of failure, and they are less concerned with evaluations of their competences by others. Entity theorists, on the other hand, would focus more on performance goals, i.e. they view achievement situations as a risk because their competencies will be evaluated and they fear negative feedback (Dweck and Leggett 1988; Robins and Pals 2002). However, recent research suggest that students can hold multiple goals at the same time and that performance goals can have beneficial effects on learning too in certain circumstances (e.g., Harackiewicz et al. 1998; Luo et al. 2011). To provide more insight into the role of the different achievement goals for learning, Elliot and Church (1997) developed a multiple goal perspective in which performance goals are replaced by performance *approach* goals (showing competence relative to others) and performance *avoidance* goals (avoiding the display of incompetence). According to Elliot and Church (1997), mastery goals are driven by achievement motivation, performance avoidance goals by fear of failure, and performance approach goals by both achievement motivation and fear of failure. Recent research has shown that holding an incremental theory predicts an additive achievement goal profile; i.e. a focus on mastery goals, negative relation with performance avoidance goals, and no relation with performance approach goals (Burnette et al. 2013; Dinger et al. 2013). Dinger et al. (2013) showed that having an incremental theory was a positive predictor of having mastery goals. In a review study on implicit theories and self-regulation Burnette et al. (2013) showed that incremental theories predict mastery goals and are negatively related to performance goals. Additionally, they found that these effects were stronger when the subjects were faced with a perceived failure or setback compared to when no such setback occurred, indicating a moderating role of perceived setbacks.

Attributions and strategies in response to failure

The third component of the motivational framework concerns a student's response to failure, i.e. the cognitive attributions a student makes to explain his/her failure and the behavioral and cognitive strategies he or she uses following failure (Blackwell et al. 2007; Hong et al. 1999; Robins and Pals 2002). These responses can be positive, i.e. a mastery-oriented response pattern, or negative, i.e. helpless response patterns. It has been shown that incremental theorists are more likely to show a mastery-oriented response (Burnette et al. 2013; Dweck 2000; Robins and Pals 2002). They attribute failure to insufficient effort and use positive strategies to overcome difficulty, such as increased effort, the use of effective problem solving strategies, and positive affect. Entity theorists, on the other hand, are more likely to adopt a helpless-response pattern, that is, they attribute failure to lack of ability, experience more negative emotions, and disengage from challenging tasks. The above-described maladaptive helpless response strategies are closely related to other forms of avoidance behavior, such as disengagement and self-handicapping. Domain disengagement is defined as a protective strategy that individuals engage in after encountering failure (Major and Schmader 1998), and describes to what extent he/she finds a domain, such as mathematics, (un)attractive, (un)important to oneself, and having (un)favorable outcomes (Steele 1997). Self-handicapping refers to withholding effort in the face of a difficult task in order to preserve the belief you *could* have done well, to evade from challenges, to procrastinate, or to ignore corrective feedback. By adopting these strategies, students bring about the failures they tried to avoid; hence the term self-handicapping. Research has found that students who use self-handicapping strategies are more likely to have performance avoidance goals (Midgley and Urdan 2001), and are more likely to hold entity beliefs (Howell and Buro 2009; Rhodewalt 1994).

Blackwell et al. (2007) showed several interrelations between these motivational variables, e.g. between effort beliefs and positive strategies. Tempelaar et al. (2015) provided results that suggest that effort beliefs mediate the relation between implicit beliefs and goal achievement. Furthermore, a direct interaction between implicit theories, self-efficacy, and achievement goals has been postulated (Dinger et al. 2013), which hypothesizes that students holding an entity theory regarding their intelligence adopt performance avoidance goals (avoiding failure) only when these entity beliefs are combined with low self-efficacy beliefs and not when these are combined with higher self-efficacy beliefs. Given these complex interrelations between these motivational variables, more empirical research is necessary to refine this third model.

Motivation and STEM educational and career choice

It has been well established that motivation is an essential factor in the prediction of educational and career choices (e.g., see Eccles 1994). However, as said before, motivation is a broad and complex construct comprising many definitions. Empirical research on the relation between the motivational constructs discussed above and STEM educational and career choice is lacking. However, we expect that each of these variables play a role in these choice processes. First, we hypothesize that negative effort beliefs have a negative impact on STEM choice behavior, specifically when a student holding negative effort beliefs also holds a negative attitude towards STEM, i.e. believing STEM related subjects require more effort and are more difficult compared to non-STEM subjects. Students holding these beliefs may be more likely to conclude that they do not have the innate ability needed to successfully engage in the 'demanding' STEM education and will therefore be less willing to put effort into pursuing a STEM major or career.

Second, the achievement goal a person holds may affect his/her learning, which might relate to educational choice. A study by Luo et al. (2011) suggests that a profile of high mastery and performance approach goals, combined with low performance avoidance goals is most beneficial for math learning, while high performance approach goals in combination with avoidance goals can have negative effects on math learning. They showed that students showing this latter, non–adaptive, profile (high approach and high avoidance goals) were less likely to control their effort and attention when faced with a difficult task, that they were lower-achievers, and were more psychologically vulnerable. This could imply that students with a mal-adaptive profile are less likely to make a STEM related choice.

Third, we hypothesize that a helpless response pattern to setbacks and challenges makes students more likely to disengage from STEM related education and careers. A study by Licht and Dweck (1984) has shown that students having a helpless response style performed worse at a mathematical task that contained confusing material compared to those showing a mastery response style. The performance of both groups was equal when no confusing material was present. Students displaying a helpless response in the context of STEM education would, for example, more often attribute their failure to not being smart enough, not being a technical person, not liking STEM subjects and they would adopt strategies such as intending to spend less time on STEM subjects, cheating on tests, or intending to drop STEM related subjects as soon as possible. These disengaging strategies are particularly interesting because they could imply that students holding entity beliefs might already disengage from STEM subjects and leak out of the STEM pipeline at an early stage in their educational training.

Last, motivation is an essential factor in the prediction of performance (Bandura 1997; Hattie 2009; Luo et al. 2011). We therefore included achievement as a possible mediator of the relation between motivation and educational and career choice. Also, Blackwell et al. (2007) showed that motivation, operationalized as achievement goals, effort beliefs, and response to failure, mediated the relation between implicit theories of intelligence and achievement, indicating that an incremental theory predicted more positive motivational patterns and that this in turn predicted increasing math grades.

Conclusion pathway 3

The findings described above provide a plausible rationale for assuming an indirect relation between students' implicit theories about intelligence and their STEM educational and career choices, mediated through motivation. The relation between entity beliefs and motivation is hypothesized to be stronger when students perceive a setback. Taken together, the reviewed studies suggest (1) that entity beliefs influence motivational beliefs, (2) that motivation mediates the influence of entity beliefs on STEM educational and career choices, (3) that setbacks and self-efficacy moderate the relation between entity beliefs and motivation, and (4) that the relation between motivation and STEM choice could be mediated by achievement.

Discussion

The shortage of students and workers in STEM related education and careers remains an ongoing concern in many countries and thus far we do not have the necessary knowledge and tools to overcome this lack of interest in STEM fields. In this theoretical article, we provided a complementary perspective by emphasizing the underlying psychological mechanisms that may influence STEM educational and career choice processes and hypothesizing that students' implicit theories about intelligence may precede and influence secondary psychological variables that are known to affect STEM choice behavior. We presented three testable models that relate implicit theories about intelligence to STEM educational and career choices via different mediating and/or moderating variables, i.e. via self-efficacy beliefs, gender, stereotypical beliefs, and motivational beliefs. Since the implicit theories of students are known to be malleable, improving these theories might prove to be a key element in stimulating and motivating students to opt for STEM related educational and career choices and in reducing the shortage of STEM students and workers. Specifying testable models, as done in this manuscript, is important for two reasons. First, it provides a necessary theoretical basis for further scientific investigation into causal relations between improvements in implicit theories, multiple psychological variables, and STEM choice behavior. And second, it provides suggestions for the development of more efficient intervention-approaches aiming to stimulate STEM choice behavior.

With the separation of the three pathways or models we do not imply that the factors in the models are necessarily independent. In fact, several interrelations between the different factors have been hypothesized in different studies. For example, Dinger et al. (2013) showed, using path analyses, relations between effort beliefs, positive strategy use, and helpless attributions. It has also been suggested that gender stereotypical beliefs not only influence career choice, but also have a negative effect on self-efficacy and math identification (Steele 1997). However, for many of these interrelations the type of hypothesized influence is not yet clear, i.e., whether factors are mediators, moderators, or are merely correlated. Therefore, we did not incorporate all such potential interrelations into one comprehensive model, but formulated simpler and more testable separate pathways of influence, based on previous outcomes from various studies on the effects of implicit theories on the one hand and research into the effects of different psychological factors on study and career choices on the other hand.

Validation of the models

Testing the models

One way to investigate the three hypothesized pathways is by means of large-scale correlational survey studies in which the scores on the variables in the models are measured among large groups of students. However, investigating the relation between implicit beliefs and self-efficacy or motivation calls for including the manipulation of a setback experience, see Fig. 1. In the most extreme case, in a correlational study, if no setback has occurred for students, one would not find any relation between their implicit theories and the other specified psychological variables. Testing the three pathways thus calls for (quasi) experimental research in which the challenge lies in modeling an ethically sound but effective setback experience before measuring the different variables. Another way of assessing the ecological validity of our theoretical models is by manipulating the implicit beliefs of students and investigating the effect hereof on the mediating variables (self-efficacy, stereotypical thinking, and motivation) and students' consecutive STEM choices. An experimental, pre-post, control-group design might show whether students with entity beliefs, who receive an intervention aimed at changing their beliefs towards more incremental beliefs, are more likely to opt for a STEM related educational or career path, compared to students with entity beliefs that did not receive such an intervention.

Additional questions

There are many additional questions that could or should be investigated in future research. For example, which pathways are the most influential for STEM educational and career choices? And are the proposed mechanisms different for different age groups? In addition, much of the research referred to in this article is conducted with a focus on implicit theories of intelligence in general. However, perceptions about your own general intelligence and perceptions about your aptitude for STEM related subjects might not be identical. Students might perceive that they can improve their intelligence in general, but hold a more fixed belief regarding their STEM aptitude, similar to observed differences in students' perceptions of their general, verbal, and mathematical abilities, as shown by Nix et al. 2015. Furthermore, we need to gain more insight into how teachers, parents, peers, or culture may influence the proposed pathways. Research has shown that parents and teachers play a major role in influencing the implicit theories of children. How does this affect the different pathways? What elements in the communication between students and teachers or parents influence implicit theories, or how do certain types of instructions and feedback exert an effect? And maybe we need to extend this investigation to include the materials and methods that students use in class to guide their educational or career choices. From our own experience, we observed that some of these materials stimulate a fixed belief about your ability to pursue certain professions and promote gender-stereotypical ideas concerning STEM professions. Mapping out these influences is essential to guide practical interventions aiming to boost STEM choices.

Instrument validation

Another very important domain for future research is the continuous validation of the measurement instruments used for investigating students' implicit theories. Most studies cited in this article make use of Dweck's three, or sometimes, four-item scale measuring entity beliefs and a comparable scale for incremental beliefs (Dweck 2000). There are some data available on the psychometric properties of these scales, especially on the discriminative validity compared to scales of self-esteem, other personal traits, such as political and religious beliefs, and cognitive and motivational needs (see Dweck 2000, p. 176 for an overview). However, to date there is no large-scale validation study in which the psychometric properties of the entity and incremental scales are investigated and compared to scales measuring effort beliefs, motivational beliefs, perceived ability beliefs, or self-efficacy. The construct of implicit beliefs is sometimes even measured using one item (see Nix et al. 2015), which does not meet psychometric standards. Furthermore, the usage of the word 'intelligence' in Dweck's items is debatable, e.g., in items such as: "Your intelligence is something about you that you can't change very much". The concept of intelligence is a psychologically broad and complex concept, which has been much debated in the scientific literature. It is therefore likely that the concept of intelligence is subject to multiple interpretations among respondents as well, which could undermine the validity of the scales. The above-described field of future research, i.e. testing of the models, manipulating implicit beliefs, investigating external influences, and instrument development will all be needed to guide the development of practical interventions aiming to stimulate STEM choice behavior. Although this will take some time to develop, meanwhile we can already specify some practical implications based on our proposed pathways. These practical considerations will be outlined below.

Practical relevance

The presented implicit theories approach to STEM educational and career choice processes provides a suggestion for intervention-approaches aiming to stimulate STEM choice behavior. If students' implicit theories about their STEM abilities indeed play a major role in STEM educational and career choices, as proposed in this article, improving these implicit theories should have a profound positive influence on students' choices. This is, for example, very relevant in light of the discussion about female participation in STEM related study paths or professions. Self-efficacy is very salient in gender-related STEM research. However, as yet, there is no clear approach how to boost such self-efficacy beliefs directly. Especially for girls that perform well on STEM related subjects in school but still have low self-efficacy beliefs. Giving them compliments on how smart they are, or telling them to believe in themselves does not seem to work. The proposed pathways suggest that it is worthwhile to try to improve their implicit theories, their related effort beliefs, and their response to failure. We need to investigate what the necessary components are of interventions aiming to change implicit beliefs in the light of STEM choices and whether the interventions can best be directed at students, teachers, parents, or, most likely, a combination of these.

Essential components of interventions

There are several components in student-targeted training or lessons that have been shown to affect the implicit beliefs of students, such as information about neuroscience with an emphasis on the plasticity of the brain and how it changes with practice (Blackwell et al. 2007; Dommett et al. 2013), creating awareness about the existence of implicit beliefs, how such beliefs may shape your response to setbacks, and the effect these beliefs may have on self-efficacy or effort beliefs and on achievement (Aronson et al. 2002; Blackwell et al. 2007; Paunesku et al. 2015), and mentoring and advising junior students using attitude change techniques emphasizing that intelligence is malleable (Aronson et al. 2002; Paunesku et al. 2015). Furthermore, one can speculate about additional components or conditions that might enhance the effect of such interventions. One of these is including cognitive challenge for each student in the curriculum. Children's implicit theories are presumably present from an early age on, but the maladaptive responses based on entity beliefs only become apparent when a student is faced with setbacks, challenges, or failures. As long as students with an entity mindset only experience success, they have no opportunity to become aware of their maladaptive response to setbacks and no opportunity to learn how to cope in a more positive way with such challenges. For many students setbacks will happen at high school and college level for the first time, where there is an increased focus on competition between students, on social comparison, and on the self-assessment of ability, which increasingly exposes students to setbacks, challenges, and failures (Blackwell et al. 2007; Eccles et al. 1993). This is especially the case for the brighter students that have had no or minimal experience with setbacks and challenges during the elementary or high school years. Providing students with challenging, higher-order, creative, and open-ended assignments is not only beneficial for stimulating bright students' capacities and thinking skills, but also gives them the opportunity to improve their self-theories and their coping mechanisms.

Furthermore, within the context of STEM, an additional component of interventions should be to create awareness about the relation between implicit theories and STEM choice processes. The pathways presented in this article can be used to explain how implicit beliefs might (unconsciously) influence STEM choices. If students become more aware of the influence of their implicit beliefs on their choice making, they might reconsider a STEM oriented study or career.

Target groups

Interventions should first of all be targeted at the students themselves with the goals of changing their implicit beliefs. It has been shown repeatedly that the implicit beliefs of students can be changed towards more incremental beliefs and that this has profound effects on motivation, enjoyment of science, and achievement (Aronson et al. 2002; Blackwell et al. 2007; Dommett et al. 2013; Paunesku et al. 2015; Schroder et al. 2014). Teachers (and preferably also parents) could be targeted in parallel, since they are known to influence the implicit beliefs of their pupils or children. Teacher professional development should serve two goals. First, teachers need to become aware of their own implicit beliefs and develop more incremental beliefs themselves if necessary. For this purpose, the components of effective interventions described above can be used. And second, teachers need to become convinced of the relevance of implicit beliefs for student motivation and achievement, and develop the necessary knowledge and skills to stimulate an incremental mindset in their students. Teachers and parents are known to have impact on students' attitudes and achievement in math and science through their own beliefs, which guide their instructional practices, expectations and interactions with children (see Bolyard and Moyer-Packenham 2008 for a review; Jacobs and Eccles 1992; Tiedemann 2002). Several studies imply that teachers who hold entity beliefs may negatively affect the beliefs and achievement of their pupils, because these teachers are more likely to (a) judge and evaluate others based on initial performance (Butler 2000), (b) make more stereotypical and extreme trait judgments of others (Levy et al. 1998), (c) display greater attention to and recognition of information that is consistent with their stereotypical beliefs (Plaks et al. 2001), and (d) are less likely to believe that they can affect student outcome (Jordan et al. 1997). Furthermore, Pomerantz and Dong (2006) showed that mothers who held high entity beliefs had a negative influence on their children's academic and affective functioning, such as grades, self-efficacy beliefs, attributions, and mastery orientations. The entity theories of the mothers acted as self-fulfilling prophecies for their children's functioning, while these self-fulfilling prophecies were absent for mothers that showed more incremental beliefs. These findings show that adults' basic assumptions regarding the nature of intelligence may have a profound impact on how they approach, judge, and stimulate their children or students. Thus, an additional necessary component of interventions targeted at teachers or parents, is knowledge about how to stimulate students and what kinds of complements to give them.

Another important aspect of teachers' professional development should be the susceptibility towards 'the attributional gender bias', i.e., the tendency to generate different explanations (attributions) for female versus male math performance (Fennema et al. 1990;

Jacobs and Eccles 1992; Räty et al. 2002; Tiedemann 2000; Yee and Eccles 1988). According to this bias, male success in math is attributed to or explained by ability, while female success in math is attributed to effort and hard work. However, when males fail in math it is usually attributed to a lack of effort, while failure of females is mostly attributed to a lack in ability. Not only parents and teachers display this tendency, students themselves also show this bias regarding their own success and failure in math (Bornholt and Möller 2003; Dickhäuser and Meyer 2006; Stipek and Gralinski 1991; Swinton et al. 2011). The attributional gender bias can be explained as a combination of entity beliefs of intelligence and gender stereotypical beliefs regarding STEM. If teachers hold an entity theory regarding intelligence, they are more inclined to attribute success and failure to ability (or lack there of) for both boys and girls. However, combining this belief with gender stereotypical beliefs about the abilities of females and males in math ('males have more innate ability for math compared to females'), will result in the attributional gender bias: If females obtain success in math, it must be due to effort, since they do not posses innate ability, while if boys fail in math, it must be due to a lack of effort, because they do possess the innate ability. Changing teachers' and parents' implicit theories regarding math ability and intelligence to more incremental beliefs should lead them to attribute success more to effort instead of ability for both boys and girls. Espinoza et al. (2014) showed that this attributional gender bias can indeed be reduced when teachers adopt more incremental beliefs regarding the nature of intelligence. However, these results were short-term, and the bias was reversed only for some teachers. The study, however, does show the potential for changing attributional gender bias through implicit theories, but also the challenges we are faced with when aiming for long-term changes. There is one very important annotation that should be addressed in communications that aim to change implicit beliefs, whether they are aimed at students, parents, or teachers, and this is to discuss the role of aptitude. Even with an extremely incremental mindset it will not be likely that anyone can become successful in everything, because aptitude or talent does play a key role. It should, therefore, be emphasized that an incremental belief about your capabilities can help in personal growth, not in being successful compared to others.

In sum, the above discussion implies that some teachers might create learning and class environments that impede achievement in STEM subjects, especially for girls, through their implicit theories, their subsequent expectations, curriculum design, teaching behavior, and their unintentional negative support through person-oriented compliments. On the positive side, many intervention studies also show the potential to improve teachers' and students' implicit theories towards more incremental beliefs about the nature of intelligence and aptitude (e.g., Blackwell et al. 2007; Dubinsky et al. 2013; Good et al. 2003). This provides guidelines for professional development to focus on improving teachers' own implicit theories, the recognition of implicit theories in children and students, and the skills to stimulate and improve incremental beliefs, in order to stimulate STEM education and career choices.

Conclusions

The presented models are a first step in stimulating STEM educational and career choices by focusing on implicit theories of intelligence. The next step is to find empirical support for these models and to develop interventions aiming to improve implicit beliefs, in order to diminish the unnecessary dropout of students out of the STEM pipeline. Of course, a measure of implicit theories cannot be used solely to predict the educational or career choices of students. Some students hold incremental beliefs (and are high achievers and have high self-efficacy beliefs), but still do not make a choice for a STEM related study path, while others tend to hold an entity belief but do pursue further STEM education because of social or economical reasons. However, for a subgroup of students, our suggested approach might be of fundamental importance and the key to stimulate them to opt for a STEM career path. It might also be a promising approach to tackle the underrepresentation of women and ethnic minorities in the STEM fields (Miller et al. 2015; National Science Foundation 2013; OECD 2008; Watt et al. 2012), for which the factors of self-efficacy and stereotypical beliefs seem to be crucial. Having more insight into the factors that precede these psychological determinants of choice behavior provides new opportunities to approach the lack of science and technologically oriented workers in western countries.

The proposed 'mindset'-approach seems to fit in with recent developments in general career choice research (not specifically focused on STEM choices) (Meijers et al. 2010). Research on general career choice processes is shifting from a static and passive vocational view (there is one vocation that suits you best, and you have to find out which one this is), to a more dynamic, self-regulating, and active view on careers. The static approach implies that students should make the best possible informed choice that best matches their own personal interests, abilities, values, and goals. Most career choice theories still adhere to this view and they approach career choice as a matching process (Gottfredson 2004, Meijers et al. 2010). The dynamic approach, on the other hand, views the student as an active learning subject, who has to adapt to new circumstances and challenges throughout his or her career, because society and vocations have become more dynamic. Examples of the dynamic approach are the Career Construction Theory (Savickas et al. 2009) and the Social Learning Theory (Pryor and Bright 2004 in Meijers et al. 2010). These theories emphasize the dynamic person, dynamic careers, and dynamic society as players in the field of career choices. Such an approach calls for students that have the knowledge, skills and attitudes to deal with new situations that they have not learned to deal with yet, corresponding to the 21st century skills of creativity and critical thinking. In our view, how students deal with these recurring choices and challenges in their career, is likely to be dependent on the implicit theories they have cultivated about the on-going potential development of their own abilities. Interventions aimed at students' study or career choices should therefore not merely focus on providing information for making the 'right' choice, but should focus on improving students' attitude towards a dynamic career and should teach students that they may shape their own careers. Taken together, we suggest that research and practical interventions in the field of STEM educational and career choice should increase their attention on the role of implicit beliefs about intelligence in choice processes.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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