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Implicit Theories of Ability, Epistemic Beliefs, and Academic Motivation:
A Person-Centered Approach

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Abstract

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The purpose of the present study was to (1) explore which distinct student profiles emerge from measures of science epistemic beliefs and implicit theories of science ability; (2) investigate how these emergent student profiles relate to science motivation and achievement; and (3) explore how these emergent student profiles differ by race/ethnicity, gender, school context (regular public school versus a STEM-focused charter school), and type of science course (life science versus physical science). Participants were 716 students from two different high schools from within the same county. One school was a regular public school and the other was a charter school that focused specifically on Science, Technology, Engineering, and Mathematics (STEM).

Cluster analysis revealed that a 4-cluster solution was the best candidate for students attending both types of schools. In addition, the cluster *patterns* were similar between schools. When controlling for prior achievement, an Analysis of Covariance revealed that students in clusters exhibiting more sophisticated stances about the nature of scientific knowledge and incremental views about the nature of ability also achieved higher science grades and exhibited more adaptive science motivation. The findings were consistent with and corroborated past variable-centered approaches investigating implicit theories of ability and epistemic beliefs. Finally, a chi-square test of independence revealed that there were differences in the composition of the student profiles as a function of race/ethnicity and by gifted status. Findings refine and extend the tenets of implicit theory of ability and epistemic beliefs.

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I thank Madeleine for her kisses—e. e. cummings was right when he wrote, "kisses are a better fate than wisdom." Finally, writing this dissertation consumed not only my own life for the past four years, but also that of my family. I am ever grateful for Amy's love and support, her blood, sweat, and tears, and her kindness and patience, especially during the many times when we thought there was no light at the end of this infinite tunnel. For this reason, I dedicate this dissertation to Madeleine and Amy.

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CHAPTER 1:

INTRODUCTION

Confronting issues of academic motivation is critical for educational researchers, teachers, and educational policy makers. Those who study questions such as why students succeed or fail in certain academic contexts must address motivational factors that influence how students perform in particular situations. Teachers who design curricula aimed at increasing student interest in the subject matter they teach must also attend to what motivates their students and what leaves them languishing in their seats. Policy makers who decide how best to design large scale instructional interventions to increase the number of women and minorities in math and science careers must investigate problems of student motivation.

Many of the motivational theories that figure prominently into current research deal with individuals' beliefs, values, and goals. For this reason, many of these theories adopt a social cognitive perspective (Wigfield et al., 2006). These motivational theories, however, are typically housed in one of several different theoretical traditions and can sometimes lead to confusion about how motivational constructs are defined and understood (Murphy & Alexander, 2000). It may appear that the study of motivation is at war with itself in trying to determine which motivational constructs are most influential in student achievement outcomes. But Pintrich (2003) argued that this is not and should not be the case. He advocated an approach "that examines how different personal and contextual factors interact to generate different patterns of motivated behavior" (p. 671).

In the present study I did exactly as Pintrich recommended—to avoid proving or falsifying the importance of single motivational constructs and to go beyond pitting personal and contextual factors and explanations against each other. Instead, I used a person-centered approach (Magnusson, 2003) to explore the various ways in which students can be motivated in science classrooms. In using this approach, I examined the patterns formed by key motivational beliefs that cross theoretical traditions. This approach advances our understanding of students' academic motivation because a large proportion of the studies investigating motivational constructs adopt a variable-centered approach using methodological techniques such as multiple regressions. However, it is possible that nonlinear relationships exist. It is also possible and likely that there are configurations of several variables that cluster to form individual profiles of students. After all, *students* achieve and *students* exhibit adaptive or maladaptive patterns of academic behavior (Magnusson & Stattin, 2006). Individual variables do not.

Thus, in the present study, I employed cluster analytic techniques to identify student profiles based on students' epistemic beliefs about the nature of scientific knowledge and their beliefs about the nature of science ability. I also explored whether these profiles differ with respect to academic achievement and other motivational variables that have figured prominently in the literature. Finally, I examined how these profiles differ with regard to demographic factors such as race/ethnicity, and gender.

The present study is divided into five chapters. In Chapter 2, I review the literature on implicit theories of ability, epistemic beliefs about the nature of science, and key motivational constructs that have figured prominently in motivation research, such as self-efficacy and goal orientations. First, I provide an overview of the social-cognitive model of achievement motivation, as outlined by Dweck and Leggett (1988), which has elicited what Dweck and her colleagues call a "meaning system" approach to motivation research. I then review the literature on how motivation constructs such as self-efficacy, self-concept, achievement goal orientations, and self-regulatory beliefs figure into Dweck and Leggett's social cognitive model of achievement motivation. I also discuss research on gender and ethnic differences in the above variables, especially in Science, Technology, Engineering, and Mathematics (STEM) fields. I also consider differences with regard to other contextual factors such as type of school curriculum. In Chapter 3, I describe the methodology. Specifically, I present the aims of the present study and the specific research questions that guide it. I also describe the participants and settings, the instruments I used in the study, and how I analyzed the data. Chapter 4 presents the results of the analyses, and in Chapter 5 I discuss the implications of my findings for science classrooms, the limitations of the present study, and directions for future work.

CHAPTER 2

REVIEW OF THE LITERATURE

The construct of implicit theories of ability has produced a large body of literature in educational research. This construct sits at the heart of Dweck's social cognitive model of achievement motivation. Thus, before I review the literature that deals with implicit theories of ability and its correlates, I provide an overview of Dweck's social cognitive model, which frames the present study.

Theoretical Framework

Implicit Theories of Ability

A long line of research has consistently shown that oftentimes what students *believe* predicts academic achievement just as well as factors such as previous achievement or standardized test scores (Bandura, 1997; Dweck & Leggett, 1988; Hong, Chiu, Dweck, Lin, & Wan, 1999; Pajares & Kranzler, 1995; Robins & Pals, 2002; Stipek & Gralinsky, 1996). What beliefs facilitate academic success? One that has received much attention in the past two decades is students' *implicit theories of ability*. According to Dweck and Leggett (1988), students adopt one of two different personal "theories" about the nature of ability. Some students adopt what is called the *entity* view of ability whereas others espouse an *incremental* view. Compared to students with an incremental view, students with an entity view are more inclined to believe that abilities are characteristics or traits that a person possesses to varying degrees and that these abilities are a relatively static entity. In contrast, students who hold an incremental view of ability are more likely than their entity theory peers to believe that abilities are an increasable and controllable quality.

Decades of research have shown that implicit theories of ability play a key role in students' academic motivation and achievement. These beliefs, as I discuss later, take on a heightened level of importance particularly during the early adolescent years and during periods of transition, such as from elementary school to middle school (Blackwell, Trzesniewski, & Dweck, 2007). Dweck and her colleagues have shown that implicit theories of ability influence students' goal orientations, their beliefs about what effort and failure mean, the strategies they employ on academic tasks, and ultimately, their academic achievement (Blackwell et al., 2007; Dweck & Leggett, 1988; Hong, Chiu, Dweck, Lin, & Wan, 1999; Robins & Pals, 2002). Because implicit theories have been shown to be related to so many motivational constructs and to academic achievement, implicit theories of ability sit at the heart of Dweck's social cognitive model and create a "meaning system" that can lead students down two different motivational and developmental paths (Hong, et al., 1999). Therefore, although students who espouse a fixed entity view of ability may be just as capable and achieve at the same levels as those who hold an incremental theory of ability, the beliefs they hold about the nature of intellectual ability may result in significantly different academic outcomes, especially when students are presented with tough challenges and setbacks.

Implicit theories can also be domain specific. Thus, some students may believe that their science abilities are a relatively stable entity while simultaneously believing that their abilities in social studies are increasable (Stipek & Gralinsky, 1996). As Bandura (1997) observed, "conceptions of ability should not be viewed as monolithic traits that govern the whole of life. The same person may view ability differently in different domains of functioning" (p. 119).

This line of research has grown out of studies dealing with maladaptive versus adaptive patterns of behavior (e.g., Diener & Dweck, 1978, 1980). In these studies, researchers devised situations in which students would attempt easy problems that all students were able to complete successfully. As the problems became more difficult and students were met with failure, the researchers observed that some students would persist and redouble their efforts in the face of difficulties, whereas others would give up immediately. Students who persisted were described as exhibiting a *mastery* pattern of behavior, and those who readily gave up in the face of difficulty were described as exhibiting a *helpless* pattern of behavior. Students who displayed a mastery pattern of behavior demonstrated a willingness to remain focused on mastering a task regardless of their present difficulties. In addition, mastery-oriented students tended not to blame their failures on their abilities. Rather, they were more likely to see difficulties as surmountable obstacles that could be successfully navigated if they employed the proper strategies and exerted the requisite amount of effort. Those who displayed the helpless pattern of behavior tended to view challenging activities as a sign of inability. These students were more likely than were those who displayed a mastery pattern of behavior to view the expenditure of additional effort as further documentation of their low ability. Students who displayed this helpless pattern also tended to fall into a pattern of solving problems using ineffective strategies even though they had been successfully using strategies on easier problems minutes earlier. When these students were met with failure, they gave up quickly. Even worse, once these students went back to the easier problems, they continued using these ineffective problem-solving strategies and continued their poor performance, even though they had succeeded on these problems before their streak of failures.

Why do students exhibit different patterns of behavior to the same situations? Dweck and her colleagues (Dweck & Leggett, 1988; Elliott & Dweck, 1988) hypothesized that these differential patterns of behavior may be linked to the goals that students pursue while engaging in problem-solving activities. As it relates to achievement-related situations, goal theorists generally use the term *achievement goal orientation* to refer to the notion that goals are not simply the general *reasons* for why students strive to achieve, nor are they just the *targets* or *standards* by which to judge oneself. Rather, goal orientations also include a number of related beliefs about how competence and success are defined, how ability and effort are viewed, how errors and setbacks are judged, and how standards of performance should be evaluated (Pintrich, 2000). Goal theorists have also given numerous labels to these different goal orientations.

Elliott and Dweck (1988) referred to these goal orientations as *learning* and *performance* goal orientations.

Students who adopt a learning goal orientation typically perform an activity because they want to increase their competence, whereas those who are primarily concerned with gaining favorable judgments from others of their competence are said to espouse performance goal orientations (Dweck & Leggett, 1988). Learning goal orientations also travel under the names *task-involved* and *mastery* goal orientations. Performance goal orientations are sometimes called *ego-involved* goal orientations. Elliott and Dweck (1988) argued that, in general, students who display a mastery pattern of behavior pursue different types of goals than do those who display a helpless pattern of behavior. The helpless pattern was usually characterized by students pursuing goals such as winning favorable judgments of their own competence or "looking smart." The researchers found that students who adopted these performance goal orientations would usually avoid challenging tasks in favor of doing tasks in which they knew they could be successful. In contrast, students who adopted a mastery goal orientation generally wanted to learn new skills, master new tasks, or understand new ideas. In other words, these students were more willing to ask questions or perform tasks that revealed their lack of skill or knowledge for the sake of learning something new.

Dweck and Leggett (1988) included one more factor in their social-cognitive approach to academic motivation—confidence, or perceived academic competence. Dweck (1999) argued that confidence is often viewed as the panacea for students' academic achievement. She contended that even though confidence is a good predictor of academic achievement, it loses its predictive power when students are met with challenging tasks. For example, in the transition from elementary school to middle school or from middle school to high school, students are often faced with academic tasks that are more difficult than anything they had previously experienced. As a result, confidence is less predictive of these students' academic achievement. In fact, students who hold a fixed view of ability are much less likely than their incremental theory peers to exhibit adaptive behavioral patterns when faced with difficulties *even if* both types of students are confident.

As Table 1 illustrates, students who adopt an incremental theory of ability are likely to adopt learning goal orientations and, *regardless of confidence*, are likely to display adaptive behavioral patterns. In contrast, students who hold an entity theory of ability are more apt to hold performance goal orientations, and only when coupled with high confidence are they likely to display adaptive behavioral patterns. According to Dweck (2002b), "students' implicit theories appear to go beyond the impact of self-efficacy" (p. 75). Bandura (1997) also suggested that "viewing ability as an inherent capacity lowers perceived self-efficacy, retards skill development, and diminishes interest in the activity" (p. 119). Other researchers have also provided some empirical support for these contentions (Bråten & Olaussen, 1998; Robins & Pals, 2002; Tabernero & Wood, 1999). This proposition, however, needs more empirical evidence, because the studies that Dweck cited to support this claim deal with sporting activities and with organizational management within businesses. Furthermore, one study Dweck cited within the academic domain used a global measure of self-efficacy on high-achieving college students in a Norwegian university. To date, no empirical support examining this claim has been conducted with high school science students.

One note should be made, however. In Dweck's model (Dweck and Leggett, 1988), confidence is defined as how certain students are about their own intellectual abilities. For example, sample items from the "confidence" measure include the following, where participants rate the degree to which they agree or disagree with these statements: "I usually think I'm intelligent;" or "I feel pretty confident about my intellectual ability." This definition differs markedly from a well studied construct that often gets mistakenly labeled as confidence—self-efficacy. Self-efficacy is defined by Bandura (1997) as one's perceived capabilities to learn or accomplish tasks at designated levels of performance. As I point out later, self-efficacy has rarely been used in studies investigating its role in Dweck and Leggett's social cognitive model.

Table 1

Implicit Theories, Goal Orientations, Perceived Competence, and Behavior Patterns in Achievement Situations (Dweck & Leggett, 1988)

Theory of Intelligence	Goal Orientation	Perceived Competence	Behavior Pattern
Entity	Performance	High	Mastery Oriented
		Low	Helpless Oriented
Incremental	Learning	High or Low	Mastery Oriented

How do students develop these beliefs about their ability? Dweck (2002b) has shown that students' conceptions of ability can be shaped by the type of feedback they receive and how that feedback is interpreted. Trait-focused feedback, such as praising students for their ability or criticizing them for not being suited for a particular activity, focuses students' attention on outcomes like receiving high grades or looking competent, rather than processes like learning to master a new skill. As Dweck argued (1999), when children are given trait-focused praise, it tends to raise their self-efficacy and helps boost their performance. Ability praise can help improve self-efficacy while students are succeeding, but when they are struggling, such attributional feedback decreases students' motivation to continue with the difficult task (Dweck, 2002b). There has been some controversy in the motivational effects of ability versus effort praise. For example, Schunk (1983) argued that students who are told that their successes on a moderately difficult task were a result of hard work have lower perceptions of self-efficacy than do those who are told that their successes were a result of ability. Therefore, though ability praise may in some cases positively influence self-efficacy, this type of praise may also encourage students to adopt an entity theory of ability. With this theoretical framework in mind, I now review the literature on implicit theories of ability.

Implicit Theories of Ability and Achievement

In the two decades since the publication of Dweck and Leggett's (1988) seminal article, research has amassed generally showing that implicit theories of ability predict academic achievement (Aronson, Fried, & Good, 2002; Blackwell et al., 2007; Hong et al., 1999; Robins & Pals, 2002; Stipek & Gralinski, 1996). In a recent study, Blackwell et al., (2007) showed that an incremental theory of ability at the beginning of junior high school predicted higher mathematics grades earned at the end of the second year of junior high school ($\beta = 0.17$), controlling for the effect of math achievement test scores before entering junior high school ($\beta = .43$). It is worth mentioning that implicit theories measured at the beginning of Grade 7 were not significantly correlated with prior math test scores (*r* ranged from -.09 to .09). Therefore, prior achievement and ability do not influence implicit theories of ability. Using growth curves computed with Hierarchical Linear Modeling (HLM), the researchers also found that an incremental view of ability predicted an upward trajectory in grades during the junior high school years, whereas an entity view of ability predicted a flat trajectory. Furthermore, in the second part of the study, the researchers conducted an intervention whereby an experimental group of students, having been taught an incremental theory, reversed their downward trend in academic achievement, whereas the control group of students continued the downward trend throughout their junior high school years. Good, Aronson, and Inzlicht (2003) also conducted an intervention with Grade 7 students using similar techniques and found that, when low-income and minority adolescents were taught to view intelligence as a malleable quality, the students earned significantly higher math test scores than did those who did not receive the incremental message. The results of these interventions suggest that the incremental message the students received had a powerful impact on reversing their downward trend in academic achievement.

Domain differences: Implicit theories and achievement. The effects of implicit theories, however, may vary depending on the domain being considered. Dweck and Leggett (1988) initially showed that implicit theories may apply to areas beyond the intellectual domain, such as in the social domain (i.e., social/personality traits like popularity are either fixed or malleable) and even the moral domain (i.e., moral characteristics such as goodness or badness are either fixed or malleable). However, they did not provide empirical evidence about whether implicit theories of ability were generalizable across *academic* domains. That is, do implicit theories of ability vary depending on which *subject matter* is being studied? Stipek and Gralinski (1996) conducted an investigation into this question and found that, contrary to their original hypothesis, students in Grades 3-6 did not espouse subject-specific beliefs about their implicit theories of ability in math and social studies. The researchers found that items measuring students' implicit theories of ability, repeated in both the domains of social studies and mathematics, loaded onto the same factor. They also found that the means for the repeated items were not significantly different from each other. Thus, there was no support for the hypothesis that elementary school students have subject-specific beliefs about the effect of ability or effort on their performance in math and social studies. However, as the researchers posited, "it is possible that, as children enter adolescence and begin to engage in higher level mathematics, their beliefs about ability related to performance in math and other subjects become more differentiated" (p. 403). In another study, Good, Aronson, and Inzlicht (2003) found that an intervention designed to teach students an incremental theory of ability helped both math *and* reading achievement, which suggests that the incremental message appeared to generalize to both academic domains.

Demographic factors: Implicit theories and achievement. As regards differences with respect to group membership, Dweck posited that high-achieving girls who have experienced much success in the elementary school years are the most vulnerable to becoming disillusioned after failures. Dweck (1999) argued that during grade school, girls typically do better in school than do boys. The highest achievers during these formative years tend to be girls, and they are typically the most vulnerable to helpless responses following challenges. Licht and Dweck (1984) and Licht and Shapiro (1982) noted that these bright girls are typically the ones who will blame their lack of ability rather than a lack of effort or appropriate strategies when they encounter obstacles. So what generally happens once students leave grade school? Some studies suggest that girls, especially girls who have experienced much success in grade school, tend to have stronger views about the fixed nature of ability (see Dweck, 1999). Stipek and Gralinski (1991) have also shown that girls typically report lower estimates of their abilities than do boys and attribute their failures more to lack of ability than do boys. In math and science classes, these patterns seem to be the most dramatic, as I will describe later.

Good, Aronson, and Inzlicht (2003) investigated differences in the effects of implicit theories between White and Black students and between women and men. They presented evidence to suggest that differences do exist. Black students responded significantly more positively to incremental messages than did White students. The incremental intervention also appeared to help female students significantly more than it did male students. In other studies comparing American students to those in Asian cultures, researchers have found that Asian students who believe in the incremental nature of ability do not necessarily pursue mastery goal orientations as was true of the American sample. Instead, Asian students were more likely to pursue performance goal orientations (Chiu, Hong, & Dweck, 1997; Kim, Grant, & Dweck, 2000). These findings suggest that teaching students an incremental theory may have different effects on academic achievement depending on the student’s gender, race/ethnicity, and cultural background.

Epistemic Beliefs

Defining epistemic beliefs. Implicit theories of ability have also been theorized to be related to epistemic beliefs (Bråten & Olaussen, 1998, 2005; Bråten & Strømsø, 2004; Hofer & Pintrich, 1997). Epistemic beliefs have received considerable attention in the past decade and describe people’s beliefs about the nature of knowledge and knowing. Epistemology, as a philosophical endeavor, is concerned with “the origin, nature, limits, methods, and justification of human knowledge" (Hofer, 2002, p. 4). However, epistemic beliefs investigated from a psychological and educational perspective deal with how people form their conceptions of knowledge and knowing, and how people utilize these conceptions to understand their surroundings. Although individuals unconsciously hold these beliefs about knowledge and knowing, they are still influenced by them. For example, although a professor may frown upon students using the popular online reference Wikipedia as a source to justify a knowledge claim, students may see this source as a legitimate authority. Therefore, different people hold different beliefs about how knowledge can be justified, and as a result make different judgments about the credibility of particular sources. As informed consumers, people make judgments about how good a particular product is by reading reviews from *Consumer Reports* or from online magazines, thereby placing an amount of trust in the certainty of knowledge claims published in these journals. As learners in a classroom, students approach learning tasks in different ways depending on whether they see the material they are learning in their science classes, for example, as being connected to or isolated from what they learn in their other classes.

Models of epistemic beliefs: The Perry model. Contemporary models of epistemic beliefs are indebted to the work of William G. Perry (1970), who is credited for being the first to empirically examine students' beliefs about knowledge. Perry's work was conducted during his years tutoring, counseling, and teaching undergraduate students at Harvard College, where he became interested in the moral and intellectual development of college students. By interviewing male undergraduates enrolled in Harvard College, Perry was able to characterize students by placing them on a continuum of beliefs from dualistic beliefs to relativistic beliefs. Dualism represented the idea that knowledge was either right or wrong. Such knowledge could only come from an authority figure such as a professor. Relativism, however, represented a view that questioned the certainty of knowledge. Students who held this perspective recognized knowledge as being complex and highly contextual.

Women's "ways of knowing." Following in the footsteps of Carol Gilligan (1982), who argued that Lawrence Kohlberg's (1969) theory of moral development excluded the experiences of women, Belenky et al. (1986) challenged Perry's scheme of epistemic development for excluding women. Perry's sample included only men from an elite private college. Belenky et al. developed a model of epistemic development based on the interviews of women who were mostly college-educated. However, the interviews were not in the context of academic learning environments. This model was known as "women's ways of knowing," which consisted of five different perspectives that represented how women view reality and come to view truth, knowledge, and authority.

Epistemological reflection. Rather than focusing specifically on one gender, Baxter Magolda (1992) interviewed both male and female college students enrolled in Miami University in Ohio and surveyed them with a measure called the Measure of Epistemological Reflection, an open-ended questionnaire. Based on the data Baxter Magolda developed four different "ways of knowing," which represented her Epistemological Reflection Model. These four views are as follows: *Absolute* knowers believe that external authorities like professionals in a field possess all the knowledge. *Transitional* knowers accept that knowledge is somewhat uncertain and that external authorities do not know everything. *Independent* knowers begin considering their own opinions as equally valid as external authorities, and challenge the assumption that authorities are the only source of knowledge. Finally, *contextual* knowers accept that authorities' claims are fallible and must be evaluated. They understand that knowledge is continually reconstructed based on new evidence. Contextual knowers judge evidence from many sources and then formulate their own view by weighing the evidence from each perspective.

Reflective judgment. King and Kitchener (1994) presented high school students, college undergraduates, graduate students, and adults not enrolled in school with a series of ill-structured problems and asked the participants questions to assess their beliefs about knowledge and how they justified their claims. After 15 years of interview studies, King and Kitchener developed and refined a seven-stage developmental model, which focused on the beliefs people possessed about the process of knowing and how knowledge claims are justified.

Argumentative reasoning. How do people reason through problems that occur in everyday life? This was the driving question that Deanna Kuhn addressed in her work with argumentative reasoning. Her participants included a broad age group (teens to people in their 60s). Participants were asked questions like "what causes prisoners to return to crime after they've been released?" Participants then explained how they came to hold their particular view and what evidence they used to support these claims. Kuhn identified the following epistemological views: *Absolutists* believe that knowledge is certain and absolute. *Multiplists* question how certain knowledge is and consider all views equally valid. And like Multiplists, *evaluativists* are also skeptical about the certainty of knowledge. However, evaluativists recognize that viewpoints can be compared and evaluated such that a person can arrive at a "better" conclusion based on the evidence.

Epistemological beliefs. Whereas the above models were created using interviews and more of a qualitative approach, Marlene Schommer and her colleagues developed a paper-and-pencil measure of these beliefs within an academic context. Guided by the question of how students' epistemological beliefs influenced students' learning, Schommer's (1990) model of epistemological beliefs broke from the unidimensional developmental view and proposed that these beliefs consist of several dimensions that more or less operate independently. These five proposed dimensions described the *structure*, *certainty*, *source* of knowledge, and the *speed* and *control* of knowledge acquisition. By independently operating, Schommer meant that individuals could possess varying levels of each of the dimensions simultaneously. For example, individuals could possess adaptive levels of the structure dimension of knowledge but also simultaneously possess maladaptive beliefs about the certainty of knowledge. One should note that the structure, certainty, and source dimensions can be traced back to Perry's original work. However, the speed and control dimensions borrow more from Dweck and Leggett's (1988) conception of implicit theory of ability, which, as Hofer and Pintrich (1997) argue, fall outside of beliefs about knowledge and knowing. Instead, these beliefs deal more with conceptions of ability and learning.

Domain-specificity. The models that take more of a developmental perspective of epistemic thinking (e.g., Perry's model or Kuhn's model of argumentative reasoning) assume that beliefs about knowledge and knowing are domain general. This becomes apparent when one considers the questions that these researchers ask their participants.

Rather than asking participants questions that require some content-specific knowledge, participants are asked very broad and general questions.

Schommer's model of epistemological beliefs also initially presumed that these beliefs were domain general. However, this implicit assumption has been called into question, especially with research showing that problem solving and critical thinking is primarily domain specific (e.g., Chi et al., 1981; Glaser & Chi, 1988). Do epistemic beliefs behave this way too? The consensus within the field is that epistemic beliefs, although having some aspects of domain generality, are also domain-specific (for reviews see Hofer, 2006; Muis, Bendixen, & Haerle, 2006). For this reason, several domain specific surveys have been developed to assess epistemic beliefs within particular academic subjects. Following the recommendations of Hofer (2006) and Muis et al. (2006) I also assume epistemic beliefs are domain specific and therefore employ a measure specific to science.

Sophistication of epistemic beliefs. Schommer's (1990) model sets each of the five dimensions on a continuum from more naïve to more sophisticated stances. This evaluative distinction, however, has been called into question and is still currently being debated. Calling certain beliefs such as the belief that the source of knowledge comes only from those in authority, is a product of Western thought (Hofer, 2008). Different cultures have different standards about what is considered naïve or sophisticated beliefs about knowledge and knowing. For example, individuals from Asian cultures generally deem it appropriate to show deference to one's elders and therefore place much trust in information from those in authority (Chan & Elliott, 2002). To deem the cultural value of trusting information from those in authority as less sophisticated is, as Hofer (2008) admonished, “pejorative” and that “greater cultural explorations may help us move away from the hegemony of western ideas of ‘sophistication’ and toward a view of epistemic understanding that is more contextual and culturally situated” (p. 16). Our conceptions of sophisticated and naïve perspectives of knowledge and knowing therefore need to be carefully considered.

Another way researchers have dealt with the issue of sophistication is to refer to them as adaptive or maladaptive. Although these terms are related to the idea of sophistication, the labels adaptive and maladaptive are tied specifically to achievement. Therefore, a particular student could believe that scientific knowledge is a personal construction rather than something that is handed down by an external authority (a more sophisticated stance) but perform worse than another student who has a more naïve view of knowledge. Therefore, for this particular student, holding a more sophisticated view of knowledge turned out to be more maladaptive than the more naïve stance. In fact, this is precisely what Bråten, Strømsø, and Samuelstuen (2008) found. Although educators and researchers certainly want to promote more sophisticated views about the source of knowledge, the authors contended that sophisticated beliefs are not universally effective and naïve beliefs are not universally ineffective. The effectiveness of a particular belief varies based on a multitude of contextual factors (Hammer & Elby, 2002; Hofer, 2006).

Therefore, in an effort to clarify terms, I will refer to “sophisticated” epistemic stances in science as ones that represent the idea that (1) scientific knowledge can be socially constructed by oneself; that (2) scientific questions can have multiple answers; that (3) science is a constantly evolving body of knowledge; and that (4) experiments in science are used to support arguments and develop new ideas. “Naïve” epistemic stances represent the idea that (1) scientific knowledge can only come from an external authority like a professional scientist or a teacher; that (2) questions in science can only have one correct answer; that (3) science is a fixed body of knowledge; and that (4) experiments are simply class projects and that they just prove that a scientific law is true. The term "adaptive" will be used to refer to stances that are associated with better achievement. The term "maladaptive" will be used to refer to stances that are associated with poorer achievement.

Relationship between implicit theories and epistemic beliefs. Researchers have begun to investigate the relationship between epistemic beliefs and implicit theories of ability (Bråten & Strømsø, 2004, 2006; Hofer & Pintrich, 1997; Schommer, 1990; Schommer, Crouse, & Rhodes, 1992). For example, Bråten & Strømsø, (2004, 2006) sought to discover the differential contribution of epistemic beliefs and implicit theories to the adoption of achievement goal orientations. Their results indicated that epistemic beliefs were significant predictors for the adoption of goal orientations, whereas implicit theories of ability were less predictive of goal orientations. Specifically, using multiple regression analyses, they found that a belief in speed of knowledge acquisition (learning either occurs quickly or not at all) was a negative predictor of mastery goal orientations ($\beta = -.26$) and a positive predictor of performance-approach ($\beta = .26$) and performance-avoid ($\beta = .37$) goal orientations. They also found that only an incremental theory of ability significantly predicted the adoption of performance-avoid goal orientations ($\beta = -.38$). Based on these results, the researchers concluded that epistemic beliefs play more important roles than do implicit theories of ability for students' adoption of goal orientations. However, the researchers used Schommer's (1990) questionnaire to assess students' epistemic beliefs.

Recall that Schommer's (1990) conception of epistemic beliefs includes two dimensions that relate more to students' beliefs about the nature of learning, which Hofer and Pintrich (1997) argued are considered peripheral constructs to the four core dimensions of epistemic beliefs. It is worth noting that the researchers found no significant correlations between the core components of epistemic beliefs (simplicity and certainty of knowledge) and goal orientations. This raises the question of whether the core components of epistemic beliefs really are more important predictors of achievement goal orientations as compared to implicit theories of ability. Clearly, more empirical evidence is needed to clarify the contribution of implicit theories of ability and the four core components of epistemic beliefs to the adoption of achievement goal orientations. Specifically, more research needs to be conducted whereby beliefs about the nature of knowledge and knowing are kept separate from constructs dealing with the nature of learning and ability, as outlined by Hofer and Pintrich.

However, even though beliefs about ability and beliefs about knowledge are separate constructs, these beliefs may be related to one another. For example, in one study investigating the epistemic beliefs and implicit theories of ability for preservice and practicing teachers, Fives and Buehl (2008) found that incremental beliefs about teaching ability (i.e., the ability to teach can be increased and honed over time) were significantly related to (a) beliefs about the importance of theoretical knowledge about teaching (i.e., the belief that it is important to have knowledge about the theory of teaching practices rather than just specific strategies or "tricks of the trade"), (b) knowledge of child and adolescent development, and (c) knowledge about content and pedagogical content (i.e., the belief that it is important to have subject-specific content knowledge as well as subject-specific pedagogical knowledge). Fixed entity views of teaching ability (i.e., the belief that teaching is an innate ability that cannot be improved) were not significantly related to these epistemic beliefs about teaching. Their findings suggest that teachers may value different types of knowledge depending on their beliefs about the malleability of teaching ability. In particular, teachers with fixed views of teaching ability, the researchers posited, may be more apt to focus on learning "tricks of the trade" rather than understanding the theoretical bases of teaching strategies. The researchers suggested that more empirical evidence needs to investigate whether beliefs about ability are in fact related to beliefs about knowledge, which their results suggested. More empirical evidence is also needed to investigate how these two beliefs *configure together* and work in concert within academic settings.

Group differences in epistemic beliefs. Although much research has been conducted examining gender differences in epistemic beliefs (e.g., Baxter Magolda, 1992; Belenky et al., 1986; Clinchy et al., 1985), some have hypothesized that there are no important gender differences in the development of epistemic beliefs (Pintrich, 2002). Pintrich has also hypothesized that when epistemic beliefs are operationalized to incorporate multiple, independent dimensions, as opposed to more holistic developmental models, no gender differences should arise in epistemic beliefs. Therefore, when students are asked to answer questions that focus on one particular domain of epistemic beliefs, there are no differences between boys and girls. Moreover, boys and girls seem to develop in their epistemic beliefs at about the same rate. Nevertheless, gender may play an important role in epistemic reasoning in ways that are undetectable. For example, Belenky et al., (1986) described “connected knowing” as a more feminine approach to knowing and learning. The approach advocates a model of teaching whereby teachers are “participant-observers” who model their thinking processes aloud to the class and aid their students in building knowledge not through competing for the “right” answer, but by building consensus (Hofer & Pintrich, 1997). However, this connected way of knowing might indeed be associated more with female students, but if male students identified with such a way of knowing, as Pintrich (2002) hypothesized, it may mean something quite different for them than for female students, and therefore manifest itself in a different way.

As for racial/ethnic differences among students there has been little empirical evidence, despite the high amount of interest in the subject. Similar to gender differences, Pintrich (2002) proposed that when epistemic beliefs are conceptualized to contain multiple independently functioning domains, there should be no differences based on race/ethnicity. Despite this proposal, the case could be made that students’ beliefs about knowledge are inextricably linked to their racial/ethnic identity. Researchers investigating other beliefs have found differences as a function of race/ethnicity. For example, Britner and Pajares (2001, 2006) have found that self-efficacy beliefs of middle school students differ based on gender and race/ethnicity. Could epistemic beliefs also exhibit differences by race/ethnicity? Chen and Pajares (2010) found that, when controlling for previous achievement among middle school science students, there were differences by race for two of the four dimensions of epistemic beliefs. In particular, when controlling for previous achievement, Asian and Hispanic students reported less sophisticated views about the source and certainty of scientific knowledge than did their White and African American peers. Clearly, there is a need for more empirical evidence to shed light on how epistemic beliefs differ as a function of race/ethnicity.

One note should be made about epistemic beliefs. The research studying epistemic beliefs in relation to academic achievement and motivation should be considered in light of the fact that there is still debate about how to define and operationalize epistemic beliefs, as the above review of the different models demonstrates. As such, the hypothesized relationships proposed by the different studies may vary depending on which measure was used. For example, Schommer's (1990) measure assumes domain generality, as mentioned above. Although this may be appropriate for studies that examine students' beliefs about knowledge in general, it may not be appropriate in circumstances when researchers want to examine epistemic beliefs in more specific domains such as high school science.

In addition, measures of epistemic beliefs vary in the number of dimensions that are included. Although Hofer and Pintrich (1997) proposed that epistemic beliefs should be thought of in terms of the four core dimensions (simplicity, certainty, source, and justification of knowledge), others have used quantitative measures that include anywhere from three dimensions (Qian & Alvermann, 1995) to five (Wood & Kardash, 2002). As mentioned earlier, some of these dimensions assess constructs like beliefs about learning, teaching, or ability, which are not central to beliefs about knowledge and knowing. For this reason, findings concerning the relationships between epistemic beliefs and academic motivation vary depending on the instrument used to assess epistemic beliefs. In the present study, I followed the guidelines set forth by Hofer and Pintrich by assessing only the four core components of epistemic beliefs, thereby keeping beliefs about knowledge and knowing separate from beliefs about the nature of ability.

Achievement Goal Orientations

Much empirical evidence supports the notion that a belief in an entity theory of ability predicts the adoption of a performance goal orientation, whereas the belief in an incremental theory of ability predicts the adoption of a mastery goal orientation (Blackwell et al., 2007; Cury et al., 2006; Dweck & Leggett, 1988; Robins & Pals, 2002). Performance goal orientations are typically defined as either pursuing a task to demonstrate one's competence to others, or to avoid a task so as not to look incompetent (Pintrich, 2000). Robins and Pals (2002) found that belief in an entity theory was associated with performance goal orientations ($r = .31$). They also suggested that an incremental view of ability was associated with learning goals. However, this conclusion was based on statistics that show that an entity theory is negatively associated with learning goals ($r = -.25$), not that an incremental theory is positively associated with learning goals. Nevertheless, this simple model has been complicated by recent research. Cury et al., (2006) suggested that further separating achievement goal orientations into performance-approach and performance-avoid as well as mastery-approach and mastery-avoid goal orientations helps to increase the precision of outcome predictions within Dweck's social-cognitive model.

Mastery-approach goal orientations are defined as striving to develop one's skills and abilities, advance one's learning, understand material, or master a task. Mastery-avoidance goal orientations entail striving to avoid losing one's skills and abilities, forgetting what one has learned, misunderstanding material, or being unable to master the material. Performance-approach goal orientations entail focusing on attaining normative competence, and performance-avoid goal orientations entail focusing on avoiding normative incompetence (Pintrich, 2000). Cury et al. showed that within this 2 x 2 achievement goal framework, entity theory was a predictor of performance-approach and performance-avoid goal orientations, and incremental theory was a predictor of mastery-approach and mastery-avoid goal orientations. In their analysis, they determined that performance-approach and performance-avoid goal orientations explained the direct relation between entity theory and academic achievement. However, the direct relation between incremental theory and academic achievement could not be explained by mastery-approach and mastery-avoid goal orientations. The researchers were able to support Dweck and Leggett's (1988) original contention that achievement goal orientations served as mediators between implicit theories and achievement. However, by using a 2 x 2 framework, the researchers were able to demonstrate that achievement goal orientations could also serve another role—as a suppressor variable. So although an entity theory led to both performance-approach and performance-avoid goal orientations, performance-approach goal orientations *suppressed* the negative direct effect of an entity theory of ability on academic performance. Consequently, adoption of an entity theory does not necessarily lead to negative achievement behavior. Rather, it is the type of performance goal adopted that predicted the ultimate achievement result.

There are discrepancies in the literature, however, concerning the relationship between implicit theories of ability and goal orientations. Bråten and Strømsø (2005) showed that entity theory of ability was not significantly correlated to mastery goal orientations but was positively correlated to performance-avoid goal orientations (r = .27).

However, using multiple regression analysis, the researchers found that entity theory of ability did not predict mastery, performance-approach, or performance-avoid goal orientations. Using multiple regression analysis, they found that incremental theory of ability did not predict mastery or performance-approach goal orientations, but did negatively predict performance-avoid goal orientations ($\beta = -.38$).

As mentioned earlier, implicit theories may be related to epistemic beliefs. Like implicit theories of ability, epistemic beliefs have also been found to be related to achievement goal orientations (Bråten & Strømsø, 2004, 2005; Garrett-Ingram, 1997; Neber & Schommer-Aikens, 2002; Pintrich, 2002; Pintrich & Zusho, 2002). This body of literature has generally shown that more sophisticated epistemic beliefs are related to more adaptive goal orientations. For example, Bråten and Strømsø (2004) showed that students who believed that knowledge is stable and given were less likely to adopt mastery goal orientations.

Self-Efficacy

According to Dweck and Leggett (1988), those who believe in an incremental theory of ability are more likely than are their entity theory peers to display a mastery pattern of behavior, which includes seeking challenges that foster learning and persisting with a task even in the face of difficulty. They contend that students who adopt the incremental theory will display this behavior pattern regardless of whether they are confident in their abilities or not. In contrast, those who hold entity views of ability are influenced by their confidence in important ways. Specifically, students who hold an entity theory of ability tend to display the mastery pattern of behavior *only if* they are confident in their abilities. This situation usually arises when students are presented with easy tasks. However, when their confidence is in question, those who possess the entity view are likely to display the helpless behavior pattern, characterized by avoiding challenges and giving up prematurely.

Dweck (2002b) argued that students who are taught an incremental theory of ability tend to be more self-efficacious than their entity theory peers. Jourden, Bandura, and Banfield (1991) found that individuals' self-efficacy beliefs for performing a motor skill task increased when they performed it under a conception that ability is incremental. However, those who performed the task under the conception that ability is fixed failed to demonstrate an increase in self-efficacy. In another study, Wood and Bandura (1989) instilled the two different conceptions of ability by telling one group that proficient management of a simulated organization reflected inherent intellectual capacity. The other group was told that performance on the same managerial task reflected an acquirable skill. The researchers found that for those who viewed ability as fixed, their self-efficacy decreased dramatically as they began to encounter problems. These participants also became more erratic in their analytical thinking and lowered their aspirations for managing the group. In contrast, for the participants who viewed ability as increasable, their self-efficacy was highly resilient even in the face of difficulties. These participants also continued to set challenging goals for the group they managed and consistently and effectively used analytic strategies. Although these studies illustrate the effects of implicit theories on self-efficacy, they were conducted in non-academic settings involving sporting activities and business management.

Investigating the relationship between implicit theories and self-efficacy in academic settings, Bråten and Olaussen (1998) studied students in a Norwegian college of education. The researchers assessed the participants' implicit theories of ability, use of learning strategies, and self-efficacy, and found that self-efficacy did not significantly correlate with implicit theories of ability. They also found that although correlations to learning strategy use for both self-efficacy (r = .24) and implicit theories (r ranged from .31 to .47) were significant, implicit theories were more strongly correlated to strategy use than was self-efficacy. Using hierarchically ordered regression analysis, the researchers also determined that, when controlling for self-efficacy, sex, and age, implicit theory accounted for an additional 5.8% of variance in the amount of learning strategies used. Thus, incremental theory of ability was a significant predictor of learning strategy use, independent of self-efficacy.

There were a number of problems in the study conducted by Bråten and Olaussen (1998). First, the researchers used a global measure of self-efficacy. Bandura (1997) argued that to predict academic outcomes with self-efficacy beliefs, "self-efficacy beliefs should be measured in terms of particularized judgments of capability that may vary across realms of activity, different levels of task demands within a given activity domain, and under different situational circumstances" (p. 6). Scores provided by global measures of self-efficacy beliefs are of limited value in predicting specific academic outcomes. Therefore, academic outcomes in a particular subject-area should be predicted using scales tailored to that same area (Pajares & Schunk, 2001). Another problem in the study concerns the measure used to assess students' implicit theories of ability. The researchers designed what they called the Conception of Intelligence Scale (CIS). Participants read 13 descriptions of intellectual qualities and then rated these qualities on a 5-point Likert scale describing the extent to which they thought that each quality could be further developed (1 = can be further developed to a very little extent; 5 = can be further developed to a very large extent). The intellectual qualities that participants were asked to rate included items such as vocabulary, understanding the essence of a problem, reading comprehension, and speed of learning. The researchers also included a single item that directly asked whether intelligence could be further developed. Therefore, although the researchers reported that conceptions of intelligence were significantly related to use of learning strategies, they reported results from the CIS measure. This is problematic in that qualities such as "understanding the essence of a problem" may not be assessing students' beliefs about intelligence. It is worth noting that the single item assessing whether students believed that intelligence can be developed was not significantly correlated with learning strategy use.

Many of the studies that have been conducted demonstrating the relationship between implicit theories of ability and Dweck's notion of "confidence in present ability" show that "confidence" moderates the influence of implicit theories and achievement goal orientations on achievement relevant outcomes (Dweck & Leggett, 1988). Dweck and Leggett proposed that confidence serves as a moderator—confidence operates independently of implicit theories of ability. However, some researchers have called this hypothesis into question (Tabernero & Wood, 1999). Tabernero and Wood argued that implicit theories of ability exert their influence on academic outcomes through the mediating influence of self-efficacy beliefs. In other words, implicit theories of ability influence self-efficacy beliefs via the interpretations of performance feedback produced by incremental versus fixed views of ability. Self-efficacy beliefs then influence the goals people set for themselves and the amount of risk they are willing to take (Bandura, 1986, 1997).

Others obtained similar results. Cury et al., (2006) found that perceived competence did not moderate the influence of implicit theories and achievement goal orientations on performance and intrinsic motivation. They found that perceived competence is best conceptualized as a predictor of achievement goal orientations, and not as a moderator for the effects of implicit theories of ability or achievement goal orientations on academic performance. Although researchers have provided much support for Dweck's social-cognitive model of implicit theories, adjustments to the model may be warranted, particularly as it relates to the role of perceived academic competence.

As for the relations between self-efficacy and epistemic beliefs, the research is much sparser. However, some empirical evidence supports the relation between these two constructs (Bråten & Strømsø, 2005; Chen & Pajares, 2010; Kizilgunes et al., 2009; Paulsen & Feldman, 2005). For example, Bråten and Strømsø (2005) found that, for a sample of student teachers in a Norwegian University, beliefs about the speed and control of knowledge acquisition (from Schommer's model) predicted general academic self-efficacy. But for business students, beliefs about the modification and certainty of knowledge predicted self-efficacy.

Self-efficacy for Self-Regulation

According to Dweck and Master (2008), an entity view of ability does not promote taking active charge of learning. An incremental view of ability, on the other hand, promotes active engagement in regulating students' own motivation and learning. Ommundson (2003) found that students with an incremental view of ability in a physical education course were more likely to change strategies when confronted with obstacles, redoubled their efforts when they encountered difficulties, and used deeper processing than did their entity theory peers. According to Dweck and her colleagues, those who espouse an incremental view of ability not only do more to manage their learning and motivation, but they also are much more willing to find and address deficiencies in their learning (Hong et al., 1999). The researchers found that entity theory students who performed poorly on a task were significantly less likely than incremental theory students to take a remedial course to address deficiencies and improve future performance. Although there have been many studies addressing the link between implicit theories of ability and self-regulation, only one study has addressed whether implicit theories of ability are related to self-efficacy for self-regulation. Chen and Pajares (2010) found that an incremental theory of ability, but not a fixed theory, was directly related to self-efficacy for self-regulation. Incremental theory and fixed theory both were indirectly related to self-efficacy for self-regulation, being mediated mostly through goal orientations.

Many researchers have investigated the relations between self-regulatory beliefs and epistemic beliefs (e.g., Hofer, 1999; Kardash & Howell, 2000; Paulsen & Feldman, 1999, 2005, 2007; Tsai, 1998). For example, Paulsen and Feldman (2005) found that more naïve views about the nature of knowledge and knowing are related to less educationally productive self-regulated motivational strategies. And although the most significant effects on self-regulated motivational strategies came from beliefs about fixed ability (a belief more in line with Dweck's notion of implicit theories), beliefs about the simplicity and certainty of knowledge did also have significant effects on self-regulated motivational strategy use. In reference to self-efficacy for self-regulation, Chen and Pajares (2010) found that although the four dimensions were not directly related to self-efficacy for self-regulation, the justification and the certainty of scientific knowledge were indirectly related to self-efficacy for self-regulation, mediated by goal orientations.

Self-Concept

Self-concept can be defined as one's collective self-perceptions that are formed through experiences with and interpretations of the environment, and are heavily influenced by reinforcements and evaluations by significant others (Shavelson & Bolus, 1982). Where self-efficacy is a judgment of capability to perform a task or engage in an activity, self-concept is a self-descriptive judgment that includes an evaluation of competence and the feelings of self-worth associated with the judgments in question (Pajares & Schunk, 2002). Questions assessing self-efficacy ask respondents to judge how confident they are that they can accomplish a particular task (e.g., "how confident are you that you can earn an "A" in your science class this semester?"). Questions assessing self-concept, on the other hand, ask respondents to reveal how positively or negatively they view themselves, as well as how they feel, in a particular subject (e.g., "is it important for you to be good at science?"). Consequently, self-efficacy beliefs are frequently referred to as "confidence" and self-concept beliefs as "self-esteem" (Pajares & Schunk, 2002). In fact, self-concept and self-esteem are often used interchangeably by researchers (Pajares & Schunk, 2001). Dweck and Leggett (1988) proposed that

> for the entity theorist, self-esteem will be fed by performance goals. Outcomes indicating the adequacy of one's attributes will raise and maintain self-esteem. However, for the incremental theorist, self-esteem

> will be acquired and experienced via learning goals. Pursuit of, progress on, and mastery of challenging and valued tasks will raise and maintain self-esteem. (p. 266)

Although Dweck and Leggett (1988) made reference to the hypothesized relationship between self-concept and implicit theories of ability, the empirical evidence to support this notion is scant. Niiya, Crocker, and Bartmess (2004) argued that research on implicit theories of ability typically “treats self-esteem as a hypothesized construct rather than a measured dependent variable.” Hypothesized relationships between self-concept and implicit theories are therefore speculative. More research is needed examining this relationship.

Interest

In a search of the literature, I identified only one published empirical study exploring the relationships between students’ interests in and commitment to pursuing a mathematics or science field and their beliefs about the nature of ability. Enman and Lupart (2000) found that beliefs about the nature of ability and the nature of knowledge predicted and were associated with interest in majoring in a science subject during college and in choosing a science subject as a favorite school subject. The authors also found that for students who indicated a science as a favorite subject endorsed a belief in fixed ability to a stronger degree than did those who indicated a non-science subject as their favorite school subject. Students who had declared a science major also had stronger beliefs about scientific knowledge being absolute and certain. Because the authors explored the beliefs of undergraduate students and academically talented high school students in a Canadian province, the generalizability of these findings is limited. More empirical evidence investigating students' beliefs about the nature of their abilities and their interest in and commitment to pursuing STEM careers is needed.

Although only one study was located examining implicit theories of ability and interest in pursuing STEM careers, there is reason to believe that such a relation exists. One can assume that indicating a science subject as a favorite subject and majoring in a science subject during college is a proxy for interest. Given this assumption, Dweck (1999) has shown that students who endorse a fixed view of ability generally do not want to pursue an activity after failing to complete a similar difficult task. However, for those who espouse an incremental theory, after failing a difficult task, these students were more likely to want to try another similar task again. In another study, Blackwell et al. (2007) found that students who were taught an incremental theory of ability were more likely to be recognized by their teachers as having reported an increased interest in learning academic material. These studies provide preliminary evidence that beliefs about the nature of science ability are related to students' interests and commitments to pursue STEM careers.

Science, Technology, Engineering, and Mathematics Fields

In science, technology, engineering, and mathematics (STEM) fields, there is considerable attention focused on the underrepresentation of women (Miller et al., 2006; Stake, 2006). Though some have argued that such an observation can be explained using biological and innate characteristics of men versus women, others have approached it from a social-cognitive perspective. Dweck (1986) posited that "the two sexes often display different motivational patterns and the fact that [mathematical subjects and verbal subjects] differ in major ways aside from the skills they require suggest that perhaps motivational patterns contribute to these achievement discrepancies" (p. 1044). Furthermore, Dweck argued that there are characteristics about mathematics versus verbal subjects that tend to work against people who display patterns that are typical of what Dweck called "bright girls" versus "bright boys," as mentioned earlier. Specifically, Dweck argued that "bright girls compared to bright boys seem to display shakier expectancies, lower preference for novel or challenging tasks, more frequent failure attributions to lack of ability, and more frequent debilitation in the face of failure or confusion" (p. 1044).

Dweck argued that after the grade school years, mathematics and science are typically taught in such a way that new skills and concepts require mastering a completely new framework. The framework for understanding algebra is not the same as that of geometry, for example. Also, the principles of biology operate on a different framework as compared to that of physics. However, with subjects such as language arts, higher levels involve more gradual increases in difficulty and operate under more similar frameworks. As a result, Dweck argued, new instructional units and higher level classes in verbal subjects simply require the student to transfer existing skills and knowledge to newer material rather than having to adopt an entirely new framework for thinking.

Grant and Dweck (2003) conducted a study to test this hypothesis. They followed premed students at Columbia University through the first semester of their chemistry class, a challenging course that typically "weeds out" those who do not perform at high levels. They found the expected male-female gender gap in science achievement. What is interesting, however, is that, among the students who reported stronger incremental views about their abilities in science, the girls outperformed the boys. For those who endorsed the view that science ability is static, boys outperformed girls. More research needs to be done to investigate the motivational role played in gender differences (Taasoobshirazi & Carr, 2008). Much more needs to be done investigating this issue with underrepresented racial/ethnic groups as well.

How do epistemic beliefs figure into issues in STEM related fields? Many of the science reform documents, for example, The American Association for the Advancement of Science's *Benchmarks for Scientific Literacy*, encourage science educators and policy makers to portray a more genuine perspective of the Nature of Science. For example, the American Association for the Advancement of Science (2009) argues that the notion that,

> scientific knowledge is always subject to modification can be difficult for students to grasp. It seems to oppose the certainty and truth popularly accorded to science, and runs counter to the yearning for certainty that is characteristic of most cultures, perhaps especially so among youth. Moreover, the picture of change in science is not simple. As new questions arise, new theories are proposed, new instruments are invented, and new techniques are developed. In response, new experiments are conducted, new specimens collected, new observations made, and new analyses performed. Some of the findings challenge existing theories, leading to their modification or to the invention, on very rare occasions, of entirely new theories. ("The Scientific World View," para. 4)

As evidenced in the above statement, science educators and policy makers are making a concerted effort to teach students about the nature of scientific knowledge and how that knowledge is produced. These efforts are directed specifically at students' epistemic beliefs about science. Despite these efforts, however, high school students still possess naïve beliefs about science (e.g., scientific experimentation is done simply to prove what we already know, rather than a purposeful activity in which scientists try to generate and test their hypotheses) (Elder, 2002; Solomon, Duveen, & Scott, 1994). Therefore, efforts in the science education community have been directed toward trying to teach students about the nature of science and how knowledge claims in science are generated.

A Person-Centered Approach

Magnusson and Stattin (2006) argued that "the traditional variable-centered approach needs to be complemented with a *person approach*, which considers a holistic-interactionistic framework" (p. 433). They argued that in using a person-centered approach, "a central implication is that the total process, which is the focus of interest in a particular study, cannot be understood by investigating single aspects isolated from other simultaneously operating components" (p. 433). Traditional approaches of estimating the unique contribution of one motivational variable to the achievement outcomes of students, *while controlling for other variables*, fail to consider aggregates of variables that operate in concert to produce effects.

An example taken from medicine may illustrate the importance of using an integrated approach. If several patients approached a doctor and told her that they had a severe headache, the doctor would want to know about other factors pertinent to each individual patient as well, to make an accurate diagnosis. A headache that is accompanied with a high fever and body aches may mean something quite different from a headache accompanied with no fever, bloodshot eyes, and vertigo. Likewise, research in motivation may be advanced by knowing not only that holding the view that one's science ability can improve is related to higher science grades, but also by investigating what other constructs, when accompanied with an incremental view of ability, act in concert to produce higher achievement.

This is not to say, however, that a variable-centered approach is inferior to a person-centered approach. According to Bergman, Magnusson, and El-Khouri (2003), variable-centered approaches are needed to help researchers isolate key constructs, which can then be used in person-centered investigations. These two approaches complement each other in much the same way that quantitative and qualitative methodologies complement each other.

The great majority of research in motivation has been conducted using a variable-centered approach. What little research has been done using a person-centered approach has typically been conducted with goal orientations (e.g., Meece & Holt, 1993; Pintrich & Garcia, 1991; Turner et al., 1998). In these studies, researchers have found that goal orientations that have been identified as maladaptive, such as pursuing a task to look smart, may in fact be beneficial if students simultaneously espouse other goal orientations, such as pursuing a task simply for the sake of learning more. For example, Pintrich (2000) used median splits to create four different groups based on their goal orientations. Comparisons were made between students classified as high-mastery/high-performance approach, high-mastery/low-performance approach, low-mastery/high-performance approach, and low-mastery/low performance approach. Recall that people who adopt mastery goal orientations pursue a task simply for the sake of learning. Those who adopt performance approach goal orientations pursue a task because they want to demonstrate to others how smart and competent they are. Pintrich found that performance approach goal orientations could serve an adaptive role, but only when accompanied by mastery goal orientations. This study employed a median split procedure, however, which imposes structure on the data based on *a priori* categories. Thus, the median split procedure tends to produce groups that are somewhat artificial.

Meece and Holt (1998) used cluster analysis to group students based on three goal orientations: Mastery, ego, and work-avoidant goal orientations. In this particular study, ego goal orientations refer to the desire to demonstrate high ability or to please the teacher. Work-avoidant goal orientations refer to a desire to complete work with a minimal amount of effort. The researchers found that students who exhibited a profile in which mastery goal orientations were stronger than the other two received higher science grades and achievement test scores. They also received higher ratings of effort by their teachers. The researchers found that the cluster analysis provided a more distinctive and internally consistent set of findings than did the median split procedure.

Investigating epistemic beliefs from a person-centered approach also appears to be promising. In the past, the lion share of research on epistemic beliefs has investigated how each individual belief factor (e.g., the source dimension of epistemic beliefs) relates to other factors such as strategy use or academic achievement. And although epistemic beliefs are believed to be multidimensional, each dimension does not exist within a vacuum. So whereas past research has shown that naïve beliefs about the simplicity of knowledge, for example, are related to poorer performance, this may be true only if accompanied by particular patterns of motivational beliefs. In fact, Bråten, Strømsø, and Samuelstuen (2008) addressed the issue of whether “sophisticated” epistemic beliefs are always better. Using median splits they found that the belief that knowledge comes from an external authority (considered to be a more naïve view of the source of knowledge) was adaptive only when accompanied by the belief that knowledge is complex (a more sophisticated belief about the simplicity of knowledge).

Buehl and Alexander (2005) also examined epistemic beliefs using a person-centered approach. However, they used cluster-analysis to uncover naturally occurring profiles of students clustered by particular variables (dimensions of epistemic beliefs, in their case). In their study, they found that the belief that knowledge is highly interrelated and that knowledge is tentative (both considered to be sophisticated beliefs) were more adaptive for learning from expository texts. This adaptability was enhanced when the above beliefs were also accompanied by the belief that knowledge can originate from personal experience rather than from external authorities only (considered to be a more sophisticated belief).

Finally, Bråten and Olaussen (2005) clustered business and nursing students in a Norwegian university based on measures of interest, mastery goals, task value, and self-efficacy. They found that a three cluster solution best fit the data, and identified the three clusters as positive motivation, moderate motivation, and low motivation profiles. Results also indicated that students in the cluster identified by the most positive motivational profile seemed more likely to believe that gaining knowledge requires much time and effort, and that knowledge is actively constructed and always evolving (all considered more sophisticated epistemic beliefs). Students in the cluster identified by low levels of motivation, however, were more likely to believe that learning occurs either quickly or not at all, and that knowledge is given and stable. All of these are considered more naïve beliefs.

The studies above point to the fact that a person-centered analysis might be a promising way to investigate academic motivation. Specifically, given the multi-dimensional nature of epistemic beliefs, cluster analysis seems especially promising in exploring the many combinations of beliefs students may hold and how these clusters of beliefs relate to motivational and achievement outcomes. However, given Hofer and Pintrich's (1997) call to keep beliefs about knowledge and knowing and beliefs about learning, teaching, and intelligence separate, there is a need to investigate student motivation profiles whereby epistemic beliefs and implicit theories of ability are conceptualized as different constructs.

Also, according to Hofer (2000) and Schommer-Aikins, (2004), there is a need to examine possible linkages between individuals' beliefs about the nature of knowledge and knowing, or their *epistemic beliefs*, cognition, motivation, and achievement. Specifically, Schommer-Aikins argued for what she called an Embedded Systemic Model approach to investigating epistemic beliefs. Under this view, epistemic beliefs do not operate within a vacuum, but rather, are conceptualized to interact closely with other aspects of cognition and motivation. At the same time, epistemic beliefs are often seen to function in much the same way as Dweck and Leggett's (1988) model of implicit theories. Specifically, both constructs are hypothesized to underlie a host of motivational and affective constructs. Dweck and Leggett hypothesized that those who believe that ability is incremental create a meaning system that sets them up for what they call a mastery-oriented pattern of behavior, which is characterized by pursuing a task simply for the sake of learning, persisting through failures, and ultimately higher levels of achievement. Likewise, more sophisticated epistemic beliefs are thought to be associated with a host of positive outcomes such as use of deeper levels of cognitive and metacognitive strategies, increased academic performance, higher levels of self-efficacy, and pursuing a task simply for the sake of learning (see Hofer & Pintrich, 1997 for a review). Given the importance of beliefs both about the nature of knowledge and knowing and beliefs about the nature of intellectual ability, and given the need to separate the two constructs, researchers can benefit from a person-centered investigation in which both constructs are studied together and seen to operate independently within the same individual student.

Statement of the Problem

Dweck (2002b) argued that "much of society is stubbornly wedded to the idea that accomplishment, especially outstanding accomplishment, is about endowment. We ignore the fact that Mozart, Darwin, Michael Jordan, and Tiger Woods practiced feverishly and singlemindedly for years, and instead believe that they were simply born with one-in-a-million ability" (p. 39). Students who adopt an entity theory of ability are more likely than are their incremental peers to believe that great accomplishments are the products of inherited endowments, therefore possibly weighting natural talent and ability over other important motivational constructs. Although there is ample research concerning implicit theories and their relationship with both achievement goal orientations and academic achievement (Aronson, Fried, & Good, 2002; Blackwell, Trzesniewski, & Dweck, 2007; Dweck & Leggett, 1988), few researchers have examined the relationship between implicit theories and other constructs that have also been prominent in the area of academic motivation, such as epistemic beliefs and self-efficacy.

Although Bråten and Olaussen (1998) studied the relationship between self-efficacy and implicit theories of ability in an academic setting, they used a global measure of self-efficacy with high-achieving Norwegian college students. Therefore, as stated earlier, self-efficacy beliefs need to be assessed at a domain-specific level.

Dweck and her colleagues have tested the relationship between implicit theories of ability and Dweck's notion of "confidence" and have shown that confidence moderates the influence of implicit theories and achievement goal orientations on achievement relevant outcomes (Dweck & Leggett, 1988). But, as mentioned earlier, some have called this hypothesis into question. Also as mentioned earlier, different researchers have used different measures of what they call confidence. For example, Tabernero and Wood defined confidence as self-efficacy. Cury et al. (2006), however, defined confidence in the same way Dweck and Leggett (1988) defined it (i.e., how confident individuals are about their intelligence). More research needs to be conducted such that the notion of confidence is clearly defined and operationalized in such a way that the measure assesses the appropriate achievement-related outcomes. Few studies have been conducted examining the role of *self-efficacy* in Dweck's social-cognitive model, and none have been conducted in the context of high school science classes.

According to Molden and Dweck (2006), Hofer (2000), and Hofer and Pintrich (1997), there is a need to examine possible linkages between implicit theories, epistemic beliefs, and students' academic motivation and achievement. Specifically, these theorists hypothesized that students' implicit theories may be closely tied to epistemic beliefs, which are themselves posited to influence a number of prominent academic motivation constructs. These constructs include achievement goal orientations, academic and self-regulatory self-efficacy, and self-concept. To date, there has been no empirical evidence to support the posited relationship between implicit theories of ability and epistemic beliefs. Though Bråten and Strømsø (2004) investigated the relative contributions of implicit theories of ability and dimensions of epistemic beliefs to the adoption of goal orientations, their work focused only on whether implicit theories or epistemic beliefs predicted the adoption of goal orientations. They did not focus on the relationships between implicit theories and epistemic beliefs, nor did they investigate how these beliefs configure, and together relate as a whole to self-efficacy, self-concept, self-regulatory beliefs, and academic achievement.

The main focus of the present study is to explore the individual belief profiles that naturally arise among high school science students. For this reason, the dominant methodological analysis in motivation research—a variable-centered approach—fails to examine how groups of variables operate as a coherent whole. Though this approach is not new to motivation research, it has been infrequently utilized. And where it has been used, it has been applied mostly to achievement goal theory, as illustrated earlier. Though Bråten and Olaussen (2005) used cluster analytic techniques, they clustered Norwegian college students based on mastery goal orientation, task value, interest, and self-efficacy and investigated how these motivation profiles differed with respect to epistemic beliefs about the speed of knowledge acquisition and knowledge construction. The researchers did not investigate the four core dimensions of epistemic beliefs, as outlined by Hofer and Pintrich (1997), and also included aspects concerning beliefs about learning, which fall outside of the epistemic beliefs construct. And although Buehl and Alexander (2005) clustered college students based on three dimensions of epistemic beliefs, their study examined beliefs in history and mathematics. In addition, their study dealt with college students rather than middle and high school students. Finally, they did not examine differences by demographic factors such as gender or race/ethnicity.

High school science classrooms provide researchers with a valuable opportunity to investigate the development of implicit theories and of epistemic beliefs, because curriculum goals in such settings often stress the importance of aiding students to achieve scientific literacy (e.g., American Association for the Advancement of Science [AAAS], 1993; National Research Council [NRC], 1996). And although scientific literacy does not have one agreed-upon definition, many of the reform documents in science education emphasize aspects that are included in types of science epistemic beliefs (e.g., scientific knowledge is tentative and subject to change and scientific knowledge is empirically based) (AAAS, 1993; NRC, 1996).

In addition, the adolescent years are generally ones that involve rapid developmental changes and a transition to more challenging educational demands (Eccles, Midgley et al., 1993; Montemayor, Adams, & Gullotta, 1990; Wigfield, Byrnes, & Eccles, 2006). High school students typically experience much more competition and social comparisons than do younger students (Eccles, Midgley et al., 1993). As a result of the transitions adolescents have to negotiate, many students experience a decline in academic achievement and school engagement that starts in middle school and continues through high school (Eccles, 2004; Wigfield, Eccles, & Pintrich, 1996). It is also thought that young children before the ages of 11 or 12 operate almost exclusively in an incremental view of ability, ascribing to the belief that smart people try hard, and that trying hard makes you smart (Dweck, 1999; Stipek, 2002). When students transition to middle school there tends to be a shift toward the belief that those who succeed without working hard must be the smart ones, and if someone has to put forth a considerable amount of effort it must be a sign of some deficit in ability. During adolescence this type of belief is thought to influence students' academic motivation (Anderman & Maehr, 1994). Examining students in high school science classrooms can therefore provide important insights into the development of students' beliefs about science ability and about the nature of scientific knowledge and knowing.

Purpose of the Study

With the above theoretical framework in mind, the purpose of the present study is to explore the individual belief profiles that naturally arise among high school science students. Cluster analytic techniques were used to create clusters based on implicit theory of ability and the four dimensions of epistemic beliefs. I also investigated how these belief profiles relate to science achievement and other prominent motivation variables. These variables include achievement goal orientations, self-efficacy, self-efficacy for self-regulation, and self-concept. Finally, I investigated how these belief profiles differ by race/ethnicity, gender, school context (regular public school versus a STEM-focused charter school), and type of science course (e.g., life science versus physical science).

Research Questions and Hypotheses

The following research questions and hypotheses guided the present study:

1) What distinct student profiles emerge from measures of science epistemic beliefs and implicit theories of science ability? Based on previous cluster-analytic research using epistemic beliefs (Buehl & Alexander, 2005), I hypothesized that subgroups consisting of strongly adaptive and strongly maladaptive beliefs about

the nature of science knowledge and knowing and beliefs about the nature of science ability would emerge. I also hypothesized that a number of subgroups consisting of mixed configurations of adaptive and maladaptive beliefs would emerge.

2) How do these emergent student profiles relate to academic achievement and other relevant motivation variables: Achievement goal orientations, self-efficacy, self-efficacy for self-regulation, and self-concept? Based on previous cluster-analytic research (Bråten & Olaussen, 2005; Buehl & Alexander, 2005), I hypothesized that adaptive profiles (e.g., clusters that include such beliefs as incremental theory of ability and the belief that knowledge is constantly evolving rather than static) would be related to mastery goal orientation and higher levels of self-efficacy, self-efficacy for self-regulation, self-concept, interest in pursuing a STEM career, as well as to higher levels of academic achievement. Student profiles that are less adaptive (e.g., clusters that include such beliefs as a fixed theory of ability and the belief that scientific experiments are simply projects people do in class rather than tools used to test hypotheses) were hypothesized to be related to performance goal orientations and lower levels of self-efficacy, self-efficacy for self-regulation, and self-concept, as well as to lower levels of academic achievement.

3) How do these emergent student profiles differ by race/ethnicity, gender, school context (regular public school versus a STEM-focused charter school), and type of science course (life science versus physical science)? Though no cluster-analytic studies have investigated these questions, previous variable-centered empirical studies and theoretical arguments (e.g., Dweck, 1999, 2006; Hofer &

Pintrich, 1997; Stipek & Gralinsky, 1991) provided some clues as to what I might find. I hypothesized that there would be differences in the emergent student profiles as a function of gender and race/ethnicity, with boys being over-represented in profiles exhibiting stronger incremental beliefs about science ability. Asian students and Hispanic students were hypothesized to be over-represented in profiles with more maladaptive source of knowledge beliefs. Asian students were hypothesized to be over-represented in profiles with more maladaptive certainty beliefs. These hypotheses were based on previous empirical results I obtained in a study on 508 Grade 6 students (Chen & Pajares, 2010). I also hypothesized that because the STEM-focused charter school serves a population of students who have an expressed interest in STEM-related careers, and because a majority of the students are in the school's gifted and talented program (students enter this program by scoring in the 96th percentile on a battery of achievement scores and aptitude tests), I hypothesized that more of these students would be over-represented in the student profiles that consist of more adaptive beliefs. Past research has demonstrated that more adaptive beliefs are typically associated with higher achievement. Finally, no directional hypotheses were advanced for whether there would be differences in the subgroups as a function of type of science course (life science versus physical science). The physical sciences and biological sciences differ in important ways (Dweck, 2006). Whereas biology (a life science) is typically characterized by memorization, classification, and identification, chemistry and physics (physical sciences), are more math intensive at the high school level. However, no research to my knowledge has investigated whether students in the two contexts differ with regard to beliefs about the nature of knowledge and knowing or beliefs about the nature of ability.

CHAPTER 3

METHODOLOGY

Keeping with the purpose of the study and the research questions mentioned above, I outline the methodology that I employed. Specifically, in this chapter I first outline the nature of the study's participants and their school. Second, I identify the instruments I used, with special attention to available data on reliability and validity. Third, I explain the process and procedures involved in collecting the data. Last, I discuss the statistical analyses that I conducted.

Participants and Setting

Participants were 716 high school science students attending two different high schools in the same county in the Southeastern United States. The first school is a regular public high school that serves over 2600 students enrolled in Grades 9-12. The racial/ethnic demographics of the school are as follows: 53% White, 20% Asian/Pacific Islander, 17% Black, and 8% Hispanic. Nine percent of the students are enrolled in Special Education, 3% are enrolled in the school's English as a Second Language (ESOL) program, and 20% qualify for free or reduced price lunch. The average total composite ACT college entrance exam score was a 24 (compared to the national average of 21.1). The average total combined SAT college entrance exam score was 1602 (compared to the national average of 1511). All subgroups of students met Adequate Yearly Progress (AYP), which includes all racial/ethnic groups, students with disabilities, and economically disadvantaged students. 95.4% of all students met or exceeded the English/Language Arts portion of the exam, and 92.1% of all students met or exceeded the Mathematics portion of the exam.

Grade 9 students in the regular public school are enrolled in biology (either at the gifted, honors, or college preparatory level. Gifted level is the highest ability group and college preparatory is the lowest ability group). Grade 10 students are enrolled in chemistry. After obtaining permission from the Institutional Review Boards of both Emory University and the county in which the schools were located, I obtained permission from students and their parents by sending home a permission slip that parents and students signed. All students were given the opportunity to participate but those who did not want to participate indicated this desire on their permission slip. In the regular public school, 1.3% of the students who were asked to participate in the study declined to participate. A total of 454 students from this school participated in the study.

The charter school is a new school in the same county, having started only in the academic year 2007-2008. This school offers a non-traditional curriculum, focused heavily on science, technology, engineering, and mathematics. Grade 9 students take two science courses, which are both year-long courses. The first is called “Advanced Physics” and the second is called “Advanced Chemistry.” Students then choose one of the following courses: “Engineering Applications” or “Intermediate Computer Programming,” both of which are also year-long courses. Grade 10 students take a year-long Advanced Placement (AP) Biology course, a year-long engineering course, and a year-long AP Calculus course. This is in contrast to the curriculum required by the state and the county, which requires Grade 9 students to take biology, Grade 10 students to take chemistry, and Grade 11 students to take physics.

Because student self-report racial/ethnic data were not available at the time of the study, teachers compiled this information based on informal observations. According to these observations, the racial/ethnic demographics of the charter school were as follows: 39% Asian/Pacific Islander, 31% White, 16% Black, and 12% Hispanic. Seventy-six percent of the students were enrolled in the county's gifted and talented program and 23% qualify for free or reduced price lunch. Because the school had yet to graduate its first class of seniors, there were no data on college entrance exams.

Written permission to conduct this investigation was obtained from both Emory University's Institutional Review Board (IRB) and that of the county in which the schools were located. Written permission was also obtained from the parents of participating students (See Appendix A for permission forms). All survey administrators were trained graduate students and received specific instructions on administering the instrument prior to the actual implementation. This ensured a standardized set of procedures.

The instrument was group administered in the participants' science classes. Students were told that the purpose of the study is to obtain their opinions about science class and about themselves as science students. They were informed that the results of the survey would be kept confidential. The Likert-type scale was explained and students were guided through the first items to ensure that they knew how to respond using this type of scale. They were encouraged to ask questions as they arose. Survey administrators were instructed to answer questions about the meanings of words or phrases that were unfamiliar to the students and, when necessary, to paraphrase items without changing their meaning.

Variables in the Study

The variables in the present study have been used by motivation researchers in investigations of science (e.g., Britner & Pajares, 2001; Conley, Pintrich, Vekiri, & Harrison., 2004; Elder, 2002; Zimmerman & Bandura, 1994). The instrument is provided in Appendix B. All motivation variables in the present study were assessed using a 6-point Likert scale. For science self-efficacy, a rating of (1) represents a response of "not at all confident" and a rating of (6) represented a response of "completely confident." For self-efficacy for self-regulation, a rating of (1) represents a response of "Not well at all" and a rating of (6) represents a response of "Very well." For all other variables, a rating of (1) represents a response of "complete disagreement" and a (6) represents a response of "complete agreement." Scores for each variable were calculated by obtaining a mean value. For academic achievement, midterm and end-of-term grades were collected in numerical form as the teachers marked them in their grade books. Grades range from 0-100.

Implicit theories of science ability. Items for the Implicit Theories of Science Ability scale were adapted from those used by Dweck (1999), and consist of six items that ask students specifically about their abilities in science rather than just their general intellectual abilities, as is the case with the original survey. Although Dweck's original scale refers to abilities in general, Stipek and Gralinski (1996) posited that adolescent students may have subject-specific ability beliefs. Therefore, items are worded so as to focus students on the subject of school science. The "self" form for children 10 years and older (Dweck, 1999) was used and worded to ensure that students focused on their ideas about their own science ability rather than on their ideas about people in general. Three items assessed students' entity theory of science ability (e.g., "You have a certain amount of science ability, and you really can't do much to change it" and "Your science ability is something about you that you can't change very much") and three others assessed their incremental theory (e.g., "No matter who you are, you can change your science abilities a lot" and "No matter how much science ability you have, you can always change it quite a bit"). When implicit theories of ability have previously been assessed, alpha coefficients have ranged from .77 to .98 (e.g., Blackwell et al., 2007; Dweck, Chiu, & Hong, 1995; Hong et al., 1999; Robins & Pals, 2002). In the present study, I obtained alpha coefficients of .87 for the incremental theory subscale and .75 for the fixed theory subscale.

Epistemic beliefs about the nature of science. Epistemic beliefs were assessed along the four core dimensions of the construct with a 26-item instrument adapted from previous work with elementary science students (Elder, 2002). All questions were worded so that students focused specifically on the domain of science. The four core dimensions that were assessed are as follows: Source (5 items) is concerned with beliefs about knowledge residing in external authorities (e.g., "Whatever the teacher says in science class is true" and "Everybody has to believe what scientists say"). Certainty (6 items) represents the belief that questions in science have one correct answer (e.g., "All questions in science have one right answer" and "Scientific knowledge is always true"). Note that the source and certainty dimensions are stated from a naïve perspective. Development (6 items) is concerned with beliefs about science as an evolving and constantly changing body of knowledge (e.g., "Sometimes scientists change their minds about what is true in science" and "The ideas in science books sometimes change"). Justification (9 items) is concerned with how students justify scientific claims, specifically as it relates to the role of scientific experiments (e.g., "Good answers are based on evidence from many different experiments" and "A good way to know if something is true is to do an experiment"). Note that the development and justification dimensions are stated from a sophisticated perspective. Conley, Pintrich, Vekiri, and Harrison (2004) used this adapted scale in a study of Grade 5 students attending five elementary schools in the Southwest and reported the following coefficient alphas for the four dimensions, each one measured at two time points: Source (alphas were .81 (t1) and .82 (t2)); Certainty (alphas = .78 and .79); Development (alphas were .57 and .66); and Justification (alphas were .65 and .76). In a recent study, Mason, Gava, and Boldrin (2008) used the Certainty and Development sections of the questionnaire and obtained an overall reliability of $\alpha = .73$. In her original scale, Elder obtained coefficient alphas for the following three dimensions: Development (.67); Justification (.52); and Source (.64). A low coefficient alpha was obtained in Elder's original scale for the Certainty dimension ($\alpha < .40$). For the present study, I obtained coefficients alpha of .78 for the Development dimension, .86 for the Justification dimension, .74 for the Source dimension, and .73 for the Certainty dimension.

Science grade self-efficacy. Students' confidence in obtaining either an A, B, C, or D in their science class was assessed using a 4-item instrument (e.g., "How confident are you that you will get a grade of "C" or better in science this semester?") (see Bandura, 1997, for assessment procedures consistent with tenets of self-efficacy theory). Students provided a rating for each of the four grades mentioned above. When researchers have used this scale in the past they have obtained coefficient alphas ranging from .85 to .91 (e.g., Britner & Pajares, 2001, 2006, 2009; Pajares, Britner, & Valiante, 2000; Usher & Pajares, 2008). I obtained a coefficient alpha of .87.

Science achievement goal orientations. Science achievement goal orientations were assessed using a scale derived from the Patterns of Adaptive Learning Survey (PALS) (Middleton & Midgley, 1997; Midgley et al., 2000) and adapted to reflect goals toward success in science class. Task goal orientations (5 items) reflect striving to develop one's skills and abilities or advance one's learning and understanding of the material (e.g., "I like science assignments I can learn from, even if I make a lot of mistakes" and "I like science assignments that really make me think"). Performance approach goal orientations (5 items) entail focusing on attaining normative competence (e.g., "I want to do better than other students in my science class" and "I would feel successful at science if I did better than most of the other students in the class"). Performance avoid goal orientations (6 items) entail focusing on avoiding normative competence (e.g., "It's important to me that I don't look stupid in science class" and "An important reason I do my science assignments is so I won't embarrass myself"). The following coefficients alpha have been reported for the following goal orientation subscales: Task (alphas ranged from .83 to .89); Performance Approach (alphas ranged from .77 to .80); and Performance Avoid (alphas ranged from .78 to .83) (e.g., Britner & Pajares, 2001; Middleton & Midgley, 1997; Pajares, Britner, & Valiante, 2000; Pajares & Cheong, 2003; Pajares & Valiante, 2001). In the present study, I obtained alphas of .86 for Task goal orientations, .80 for Performance Approach, and .80 for Performance Avoid.

Science self-concept. Science self-concept describes students' perceptions about their science ability and their feelings of self-worth associated with this ability (e.g., "It is important to me to get good grades in science" and "I enjoy doing science work."). This construct was assessed with the 6-item science scale from Marsh's (1990) Academic Self Description Questionnaire (ASDQ-1). Researchers who have used this scale in the past with science students and in areas such as language arts and mathematics have reported coefficients alpha ranging from .81 to .94 (e.g., Britner & Pajares, 2001, 2006; Marsh, 1990; Pajares & Valiante, 2001; Usher & Pajares, 2008). I obtained an alpha coefficient of .91.

Self-efficacy for self-regulation. Self-efficacy for self-regulation in science was assessed using a 7-item subscale adapted from Bandura's Children's Multidimensional Self-Efficacy Scale that assesses students' judgments of their capability to use various self-regulated learning strategies (e.g., "How well can you study when there are other interesting things to do?" and "How well can you finish your homework on time?") (Zimmerman & Bandura, 1994). A validation study by Zimmerman and Martinez-Pons (1988) revealed that a single factor underlay the items. Researchers have reported coefficient alphas ranging from .78 to .87 (e.g., Britner & Pajares, 2001, 2006; Pajares, Miller, & Johnson, 1999; Usher & Pajares, 2006; Zimmerman, Bandura, & Martinez-Pons, 1992). I obtained an alpha coefficient of .81.

Interest in pursuing STEM-related careers. Three questions assessed whether students expressed an interest in pursuing a Science, Technology, Engineering, and Mathematics (STEM)-related career. First, students were asked to write down three jobs they realistically see themselves pursuing after school ("On the blanks below, name up to three types of jobs you could realistically see yourself pursuing"). Second, students were asked to circle the one job they are most interested in pursuing ("Of the three jobs you listed, circle the one you are most interested in pursuing"). Finally, students were asked to rate, on a scale from "1" (Not at all confident) to "6" (Completely confident), how confident they are that they will pursue the job they circled ("How confident are you that you would pursue this job? Circle one of the numbers (1-6) below"). All three jobs/careers that the students enter on their survey were coded as either STEM career or not a STEM career. I consulted *The Occupational Outlook Handbook* distributed by the U.S. Department of Labor's Bureau of Labor Statistics in classifying these jobs/careers as STEM careers or not. I also coded these jobs/careers as whether they require a 4-year degree or not to indicate what type of STEM career these students are indicating (e.g., "blue collar" versus "white collar" STEM careers). To validate the coding, one other researcher followed this procedure to classify the occupations. Discrepancies in coding were resolved through discussion.

Demographics and achievement. Students self-reported their grade level, age, gender, and race/ethnicity. Achievement data, in the form of grades in students' core academic subjects (math, science, language arts, and social studies) were obtained from students' school records.

Analysis

Data were first examined for outliers, missing values, and accuracy. Question 1 examined the distinct student profiles that emerge from measures of science epistemic beliefs and implicit theories of science ability. Cluster analysis was used to test the hypothesis that a group of beliefs functions as a whole within an individual student. This method of analysis allowed me to treat an individual student's cluster or group of beliefs as a single unit. By doing so, this method of analysis can uncover distinct student profiles or patterns that display varying levels of each of the four dimensions of epistemic beliefs and implicit theory of ability. In other words, whereas past research has been able to uncover specific beliefs that are important for the academic success of students, the present study investigated which *constellation* of beliefs, organized within actual individual students, is associated with different levels of academic motivation and achievement.

The theoretical framework that undergirds this person-centered analysis is one in which a group of beliefs operates in concert within an individual. Although there are a number of methods to analyze data from a person-centered perspective (e.g., Q-sort technique and latent profile analysis), I employed cluster analytic techniques in the present study. This technique has been used before in studies of academic motivation in general (e.g., goal orientations) and with epistemic beliefs in particular (e.g., Buehl & Alexander, 2005). It is important to note that different methods of analysis are simply different "tools" used to understand how processes function. As Magnusson and Stattin (2006) argue, "tools are never good or bad in themselves. The appropriateness of a particular statistical method for a particular study depends on how effectively it contributes to a correct answer to the problem" (p. 443).

In the present study I was concerned with discovering naturally occurring patterns of beliefs among students in science classes. For this reason, I employed a method of analysis that forms homogenous groups of students. Ward's hierarchical clustering technique (Ward, 1963) was used because it is considered to be especially effective in recovering the underlying structure of a given data set (Atlas & Overall, 1994; Blashfield, 1996). Ward's technique was used also because it has been successfully employed in previous empirical studies investigating learner profiles (Alexander, Jetton, & Kulikowich, 1995; Alexander & Murphy, 1998; Bråten & Olaussen, 2005; Buehl & Alexander, 2005). Ward's technique is considered an agglomerative method, which means that at the start of the procedure, each individual represents a unique cluster. In the final cluster solution, all individuals are placed in a particular group in which differences between students *within* a cluster are minimized but differences *between* groups are maximized (Aldenderfer & Blashfield, 1984).

Cluster analytic techniques are not without their weaknesses. Some have criticized cluster analysis for its instability. In other words, different methods of clustering may produce different cluster solutions. Bergman et al. (2003) however, noted that if the methodological approach closely matches theory, this instability is rare. In addition, to examine if the cluster solutions differ by school (regular school versus charter school) and by type of science course (physical science versus life science), I analyzed each of the four groups separately using identical procedures. The cluster solutions for each group were then compared to determine if the emergent profiles were consistent between groups.

Following Aldenderfer and Blashfield (1984) and Everitt et al. (2001), I used dendrograms (graphical representations of the clustering procedure) to aid in uncovering the number of potential clusters. Next, each of these distinct clusters were compared to determine significant differences between the clusters with respect to the clustering variables of interest (the four dimensions of epistemic beliefs and implicit theory of ability). Discriminant function analysis was used to validate the cluster solution. In performing this analysis, I used an analysis of covariance (ANCOVA) to test for statistically significant differences on the variables used to form the cluster, while controlling for previous science achievement.

Question 2 examined how the emergent profiles relate to academic achievement and achievement goal orientations, self-efficacy, self-efficacy for self-regulation, self-concept, and interest in pursuing a STEM career. An analysis of covariance (ANCOVA) was performed with cluster group membership as the independent variable and the relevant motivation variables as the dependent variables. Previous science achievement was again included as a covariate. Tukey's pairwise multiple comparisons were used to identify the sources of these differences between clusters.

Finally, to explore how the emergent student profiles differ by race/ethnicity, gender, school context (regular public school versus a STEM-focused charter school), and type of science course (life science versus physical science), I conducted a chi-square test of independence. Using this analysis, I was able to explore which profiles are overrepresented by students of particular racial/ethnic backgrounds, by boys or girls, by regular public school students or STEM-focused charter school students, and by life science or physical science students.

CHAPTER 4

RESULTS

The first objective of the present study was to explore which distinct student profiles emerged from measures of science epistemic beliefs and implicit theories of science ability. The second objective was to examine how these emergent student profiles relate to academic achievement and motivation. The final objective was to examine how these emergent student profiles differ by race/ethnicity, gender, school context (regular public school versus a STEM-focused charter school), and type of science course (life science versus physical science). Before I present the results of the above objectives, however, I provide preliminary analyses regarding the reliability of the cluster solutions.

Reliability of Cluster Solutions

As mentioned earlier, one of the criticisms of cluster analysis is that cluster solutions may be difficult to replicate. To ensure the stability of the cluster solutions, I checked for the sensitivity of the results due to variations in sampling. This was accomplished by analyzing random split halves of the full sample separately using the same procedures, as outlined in chapter 3. Second, I divided the full sample by the type of school in which students were enrolled (regular public school versus STEM charter school) and used the same clustering procedures to analyze these two school samples. Finally, I divided the full sample by the type of science class in which the students were enrolled (physical science versus life science) and used the same clustering procedures to analyze these two science samples.

Split Random Halves

I conducted an identical set of analyses on random halves of the full sample of students. There were 716 students with complete data. The 3-, 4-, and 5-cluster solutions were examined and a 4-cluster solution was determined to be the best candidate for both random halves. Table 2 shows the means and standard deviations for the variables used in forming the 4-cluster solution, split by random half. These data are graphically represented in Figures 1 and 2.

The 4-cluster solution provided the most amount of information while balancing the need for a parsimonious solution. In the 3-cluster solution there were two groups that displayed sophisticated epistemic beliefs, with one group displaying a strong incremental theory and the other displaying a very weak incremental theory. There was a third group that displayed a moderate implicit theory along with more naïve epistemic beliefs than the other two groups across all four dimensions. However, the 4-cluster solution produced two clusters that displayed a mixture of adaptive and maladaptive beliefs. For example, for the first split half, the 4-cluster solution produced Groups 2 and 4, where Group 4 seemed to display maladaptive beliefs across all five variables, whereas Group 2 displayed a mixture of adaptive and maladaptive beliefs. This extra group provided by the 4-cluster solution allowed me to better explore potential similarities and differences in motivation and achievement among all the groups. In contrast, the 5-cluster solution did not provide any additional information that the 4-cluster solution already provided, and was therefore less parsimonious.

There was a considerable amount of overlap in the two random halves. For example, In Split-Half #1, Clusters 3 and 1 corresponded closely with Clusters 2 and 4,

Table 2. *Means and Standard Deviations for Clustering and Motivation Variables in the Study by Split Half*

	RANDOM SPLIT HALF #1								RANDOM SPLIT HALF #2							
	Cluster 1 (n = 132)		Cluster 2 (n = 86)		Cluster 3 (n = 64)		Cluster 4 (n = 76)		Cluster 1 (n = 113)		Cluster 2 (n = 59)		Cluster 3 (n = 120)		Cluster 4 (n = 66)	
Variables	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
Clustering Variables[1]																
Implicit Theory of Ability	**3.8c**	0.8	**4.9b**	0.8	**5.5a**	0.7	**3.8c**	0.9	**5.2a**	0.7	**4.8b**	0.7	**4.1c**	0.7	**3.0d**	0.7
Epistemic Beliefs (Source)	**2.2c**	0.8	**3.6a**	0.8	**1.9d**	0.8	**3.1b**	0.9	**2.8b**	0.7	**1.6d**	0.7	**3.5a**	0.8	**2.2c**	0.7
Epistemic Beliefs (Certainty)	**1.8c**	0.6	**2.7b**	0.6	**1.4d**	0.6	**2.9a**	0.7	**2.0b**	0.6	**1.3c**	0.6	**2.9a**	0.6	**2.1b**	0.6
Epistemic Beliefs (Development)	**5.5b**	0.6	**5.4b**	0.6	**5.7a**	0.5	**4.6c**	0.6	**5.4b**	0.6	**5.8a**	0.6	**4.7c**	0.6	**5.3b**	0.6
Epistemic Beliefs (Justification)	**5.3b**	0.6	**5.3b**	0.6	**5.6a**	0.5	**4.6c**	0.6	**5.4a**	0.6	**5.6a**	0.6	**4.9c**	0.6	**5.0b**	0.6
Motivation[2]																
Self-Efficacy	**4.7b**	1.0	**5.2a**	1.0	**5.3a**	1.0	**4.8b**	1.1	**5.1a**	1.0	**5.2a**	1.0	**4.9ab**	1.1	**4.6b**	1.1
SE for Self-Regulation	**3.9b**	0.9	**4.3a**	1.0	**4.5a**	0.9	**3.8b**	1.1	**4.4a**	0.9	**4.3a**	0.9	**4.2ab**	1.0	**3.9b**	1.0
Self-Concept	**3.9b**	1.1	**4.5a**	1.1	**4.6a**	1.0	**3.7b**	1.2	**4.4a**	1.0	**4.2ab**	1.0	**4.0b**	1.1	**3.7c**	1.1
Mastery Goal	**3.9b**	1.1	**4.4a**	1.1	**4.7a**	1.1	**3.6b**	1.3	**4.3a**	1.1	**4.5a**	1.1	**4.0b**	1.2	**3.5c**	1.2
Performance Approach Goal	**4.4ab**	1.1	**4.7a**	1.1	**4.4ab**	1.1	**4.1b**	1.3	**4.5a**	1.1	**4.3a**	1.1	**4.4a**	1.2	**4.2a**	1.2
Performance Avoid Goal	**3.0**	1.1	**3.0**	1.2	**2.6**	1.1	**3.1**	1.3	**2.8**	1.2	**2.7**	1.2	**3.2**	1.3	**3.4**	1.2
Achievement[3]	(n = 104)		(n = 71)		(n = 54)		(n = 59)		(n = 90)		(n = 45)		(n = 82)		(n = 47)	
Final Science Grade	**84.6a**	10.6	**86.7a**	8.0	**85.4a**	10.9	**78.3b**	11.2	**85.5a**	8.7	**86.3a**	8.6	**80.7b**	11.9	**83.1a**	11.6

Note . Means range from 1 (low) to 6 (high). Means for achievement range from 1-100. Means for a dependent variable (row) that are subscripted by different letters and in bold are statistically different (experiment-wise α < .05) computed on an effect identified by ANCOVA. Mean scores for the ANCOVA analyses were adjusted for previous achievement. Mean differences for achievement were computed on a effect identified by MANOVA. Superscripts represent separate analyses.

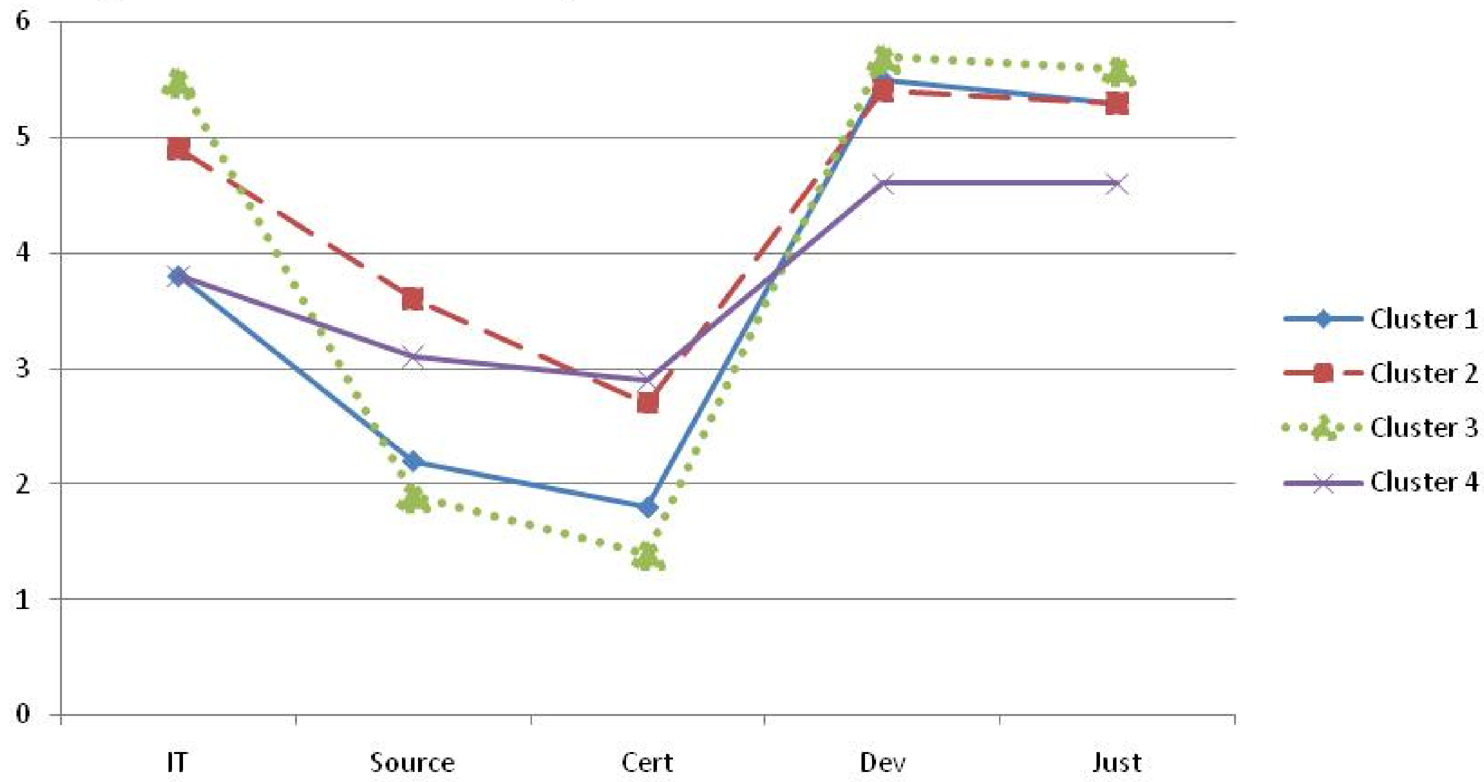
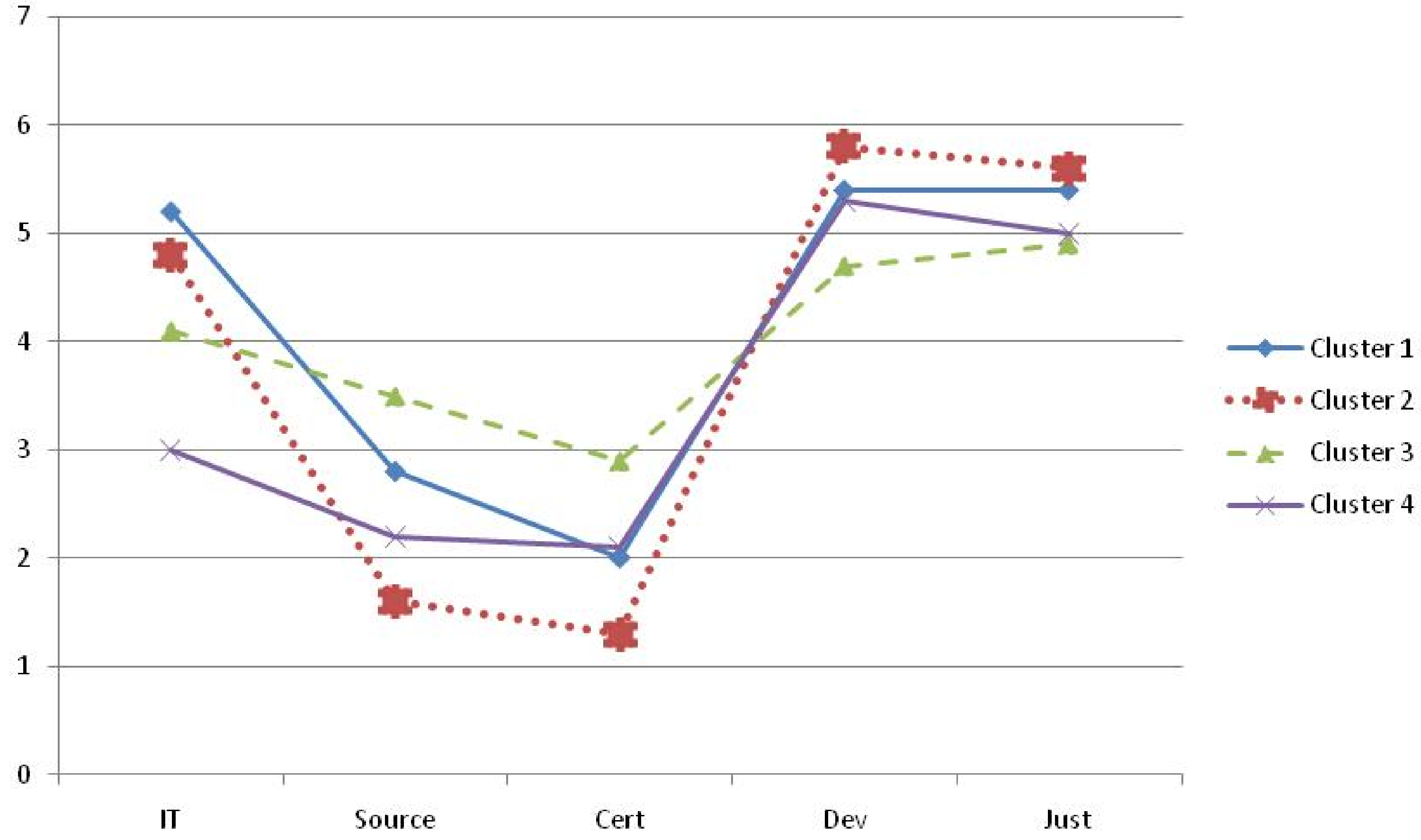


Figure 1. 4-Cluster Solution for Split-Half #1.

Figure 2. 4-Cluster Solution for Split-Half #2.



respectively, from Split-Half #2. And Clusters 2 and 4 from Split-Half #1 corresponded with Clusters 1 and 3, respectively, from Split-Half #2. And although there were some discrepancies, they were not concerning because the cluster patterns were closely matched to achievement and motivation outcomes, as can be seen in Table 2. For example, even though the relative positioning of the implicit theory, Source, and Certainty measures for Cluster 2 in Split-Half #1 are slightly different from that of its counterpart in Split-Half #2 (Cluster 1), they still are related to similar relative rankings with regard to motivation variables and achievement. The same holds true when comparing Cluster 4 in Split-Half #1 with its counterpart in Split-Half #2 (Cluster 3).

Split by School

I split the full sample of students by school attended and conducted an identical set of analyses for each sample. There were 454 students attending the regular public school who had complete data and there were 262 students attending the STEM charter school who had complete data. The 3-, 4-, and 5-cluster solutions were examined and a 4-cluster solution was determined to be the best candidate for both schools. Table 3 shows the means and standard deviations for the variables used in forming the 4-cluster solutions, split by school. These data are graphically represented in Figures 3 and 4.

The 4-cluster sample was also the most parsimonious solution, while providing the most amount of information. As with the split halves the 4-cluster solution was able to provide more information than the 3-cluster solution for the groups of students that had a mix of adaptive and maladaptive beliefs. For example, the second cluster of the 3-cluster solution was split into the Cluster 2 (Uncommitted) and Cluster 3 (Passive) groups.

Table 3. *Means and Standard Deviations for Clustering Variables in the Study by School and Cluster.*

	REGULAR PUBLIC SCHOOL								STEM CHARTER SCHOOL							
	Cluster 1 (Ideal) (n = 164)		Cluster 2 (Uncommitted) (n = 37)		Cluster 3 (Passive) (n = 113)		Cluster 4 (Fixed) (n = 140)		Cluster 1 (Incremental) (n = 83)		Cluster 2 (Ideal) (n = 70)		Cluster 3 (Simplistic) (n = 94)		Cluster 4 (Fixed) (n = 15)	
Variables	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
Clustering Variables[1]																
Implicit Theory of Ability	**5.2a**	0.8	**3.8bc**	0.9	**4.0b**	0.8	**3.6c**	0.7	**5.4a**	0.7	**4.8b**	0.7	**4.1c**	0.7	**2.7d**	0.7
Epistemic Beliefs (Source)	**2.4bc**	0.9	**2.7b**	1.1	**3.8a**	1.0	**2.2c**	0.9	**3.1a**	0.7	**1.8b**	0.7	**3.2a**	0.7	**1.9b**	0.7
Epistemic Beliefs (Certainty)	**2.0c**	0.7	**2.8b**	0.8	**3.2a**	0.7	**1.9c**	0.6	**2.0b**	0.5	**1.4c**	0.5	**2.7a**	0.5	**1.5c**	0.5
Epistemic Beliefs (Development	**5.4a**	0.6	**3.9c**	0.7	**4.9b**	0.6	**5.4a**	0.6	**5.6a**	0.5	**5.7a**	0.5	**5.0b**	0.5	**5.6a**	0.5
Epistemic Beliefs (Justification)	**5.4a**	0.6	**3.9d**	0.7	**4.9c**	0.6	**5.1b**	0.6	**5.6a**	0.5	**5.6a**	0.4	**5.0b**	0.5	**5.1b**	0.4
Achievement[2]																
Final Science Grade	**86.1a**	9.2	**75.1c**	13.7	**80.0bc**	13.2	**82.9ab**	10.3	**86.8a**	8.8	**87.1a**	8.8	**82.5b**	9.1	**86.9ab**	8.0

Note. Means range from 1 (low) to 6 (high). Means for a dependent variable (row) that are subscripted by different letters and in bold are statistically different (experiment-wise α < .05) computed on an effect identified by ANCOVA. Mean scores for the ANCOVA analyses were adusted for previous achievement. Superscripts represent separate analyses. Regular (n = 454), Charter (n = 262).

Figure 3. 4-Cluster Solution for Regular Public School: Clustering Variables.

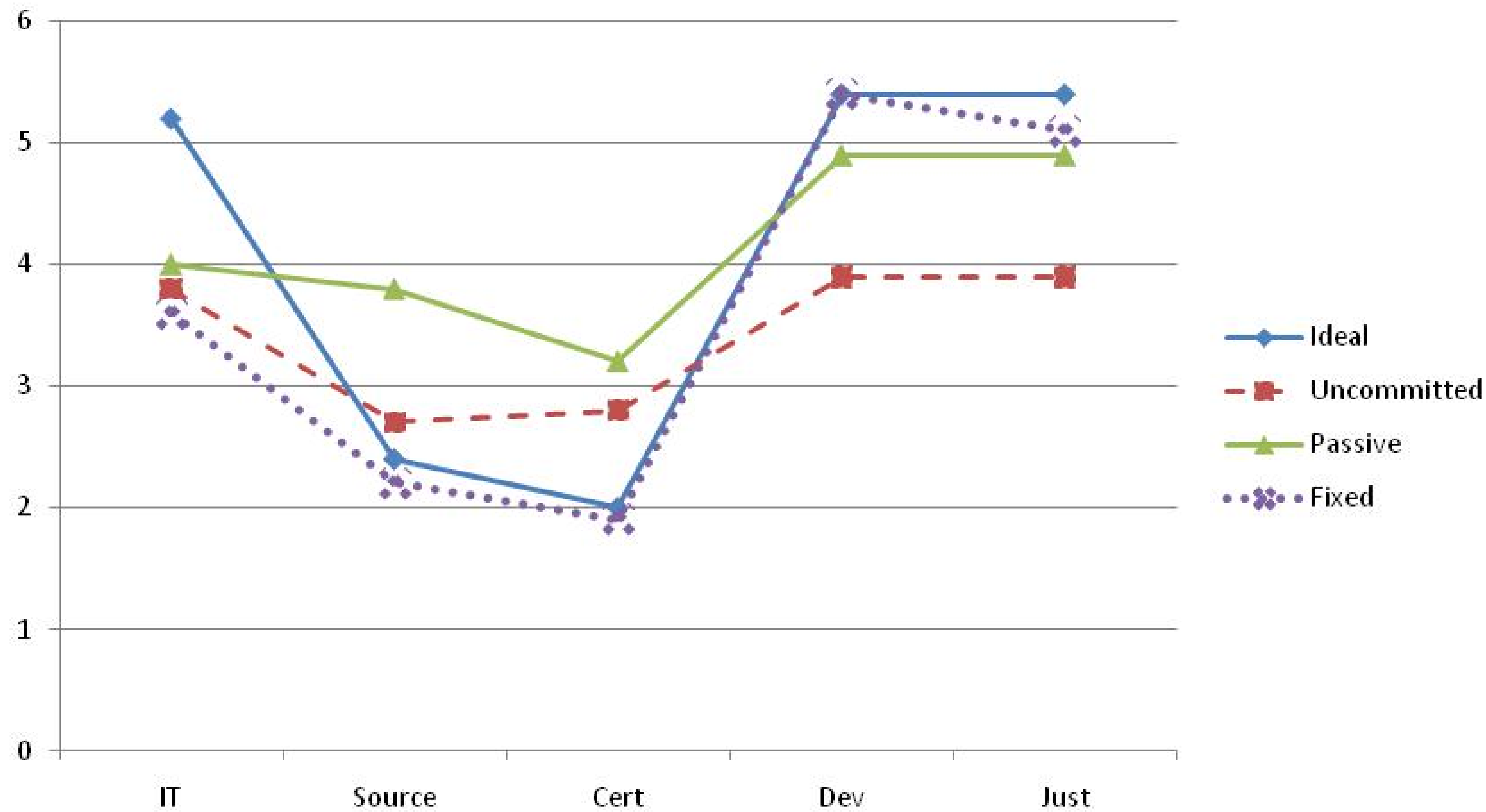
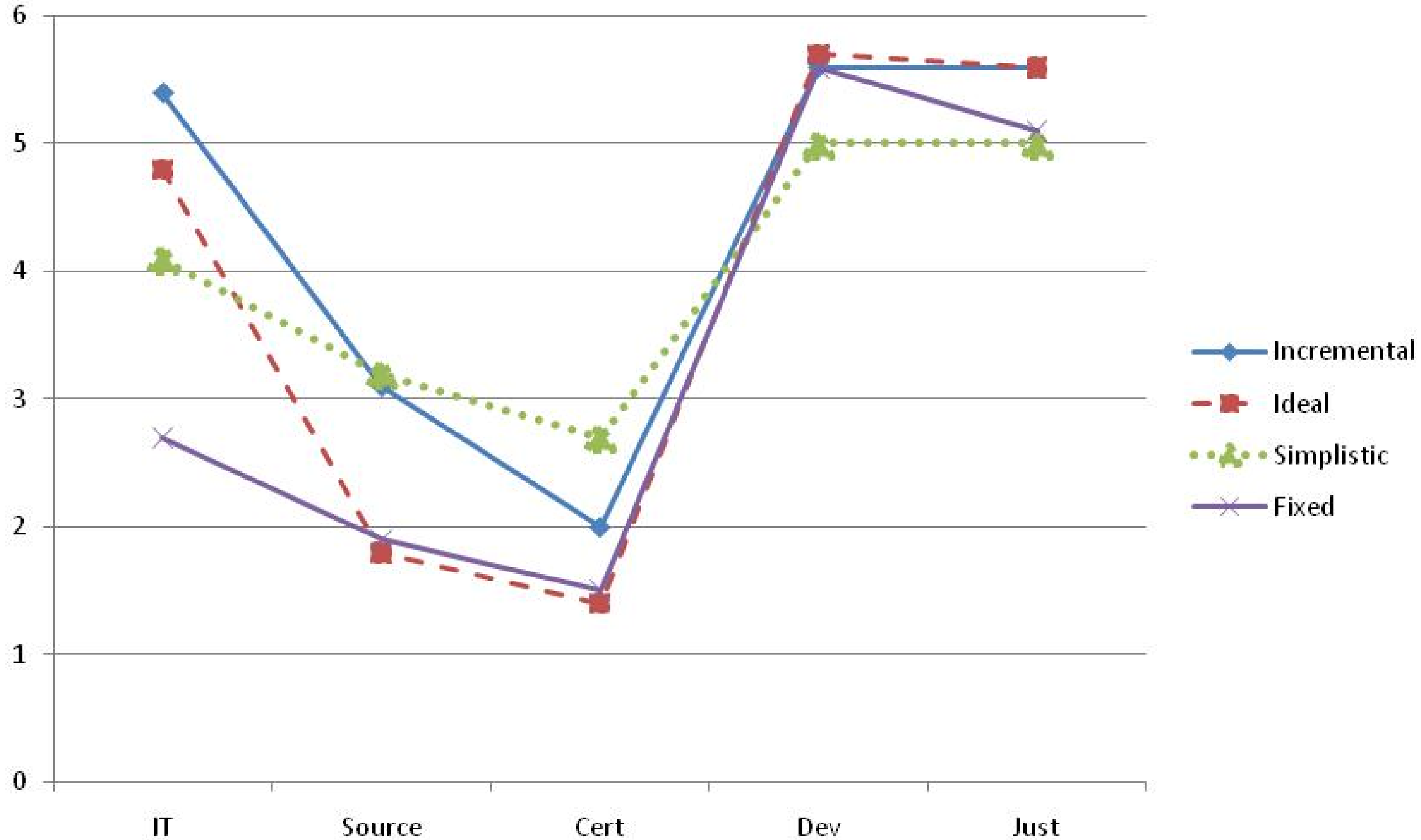


Figure 4. 4-Cluster Solution for Charter School: Clustering Variables.



By doing so, I could explore whether sophisticated Source and Certainty beliefs, combined with unsophisticated Justification and Development beliefs (Uncommitted) would differ from a group with unsophisticated Source and Certainty beliefs and sophisticated Development and Justification beliefs (Passive). The 5-cluster solution, however, did not provide any additional information that the 4-cluster solution did not already provide. As with the split random halves, there was strong correspondence between the cluster patterns of the two school samples. This provided additional evidence for the reliability of the cluster solutions.

Split by Science

Finally, I split the full sample of students by the science class in which they were enrolled and conducted an identical set of analyses for each sample. There were 392 students enrolled in a physical science class who had complete data and there were 324 students enrolled in a life science class who had complete data. Again 3-, 4-, and 5-cluster solutions were examined and a 4-cluster solution was determined to be the best candidate for both schools. Table 4 shows the means and standard deviations for the variables used in forming the 4-cluster solutions, split by science class. These data are graphically represented in Figures 5 and 6.

Like the above cluster solutions, the 4-cluster solution was the most parsimonious. For example, for the physical science group, Cluster 3 in the 3-cluster solution split into Clusters 3 and 4 in the 4-cluster solution. This split added an extra profile that kept implicit theory constant while gaining more separation with the four dimensions of epistemic beliefs. The 5-cluster solution added no new information that the 4-cluster solution did not already provide. Clusters 1, 2, and 3 from the physical sciences

Table 4. *Means and Standard Deviations for Clustering and Motivation Variables in the Study by Science Curriculum.*

	PHYSICAL SCIENCES								LIFE SCIENCES							
	Cluster 1 (n = 132)		Cluster 2 (n = 117)		Cluster 3 (n = 88)		Cluster 4 (n = 55)		Cluster 1 (n = 97)		Cluster 2 (n = 92)		Cluster 3 (n = 79)		Cluster 4 (n = 56)	
Variables	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
Clustering Variables[1]																
Implicit Theory of Ability	**5.1a**	0.7	**4.8b**	0.7	**3.4c**	0.7	**3.6c**	0.8	**3.5d**	0.7	**4.1c**	0.8	**5.4a**	0.7	**5.1b**	0.8
Epistemic Beliefs (Source)	**2.0d**	0.8	**3.5a**	0.7	**2.3c**	0.7	**3.2b**	0.9	**2.2b**	0.7	**3.6a**	0.8	**2.1b**	0.7	**3.3a**	0.8
Epistemic Beliefs (Certainty)	**1.6d**	0.6	**2.7b**	0.6	**2.1c**	0.6	**3.0a**	0.7	**1.7c**	0.7	**3.0a**	0.7	**1.7c**	0.7	**2.1b**	0.7
Epistemic Beliefs (Development)	**5.6a**	0.6	**5.0c**	0.6	**5.3b**	0.6	**4.2d**	0.7	**5.6a**	0.5	**5.0b**	0.6	**5.6a**	0.5	**5.6a**	0.6
Epistemic Beliefs (Justification)	**5.6a**	0.6	**5.2b**	0.6	**5.2b**	0.6	**4.1c**	0.6	**5.3b**	0.5	**4.9c**	0.5	**5.6a**	0.5	**5.4ab**	0.6
Motivation[2]																
Self-Efficacy	**5.0a**	1.1	**4.9a**	1.1	**4.5b**	1.1	**4.3b**	1.3	**4.9b**	0.8	**5.3a**	0.8	**5.3a**	0.8	**5.4a**	0.9
SE for Self-Regulation	**4.3a**	0.9	**4.3a**	0.9	**4.0b**	0.9	**3.7b**	1.1	**3.8b**	0.9	**4.2a**	1.0	**4.4a**	0.9	**4.3a**	1.0
Self-Concept	**4.4a**	1.1	**4.3a**	1.1	**3.7b**	1.1	**3.2b**	1.2	**3.8b**	1.0	**4.3a**	1.0	**4.5a**	1.0	**4.4a**	1.1
Mastery Goal	**4.5a**	1.1	**4.2a**	1.1	**3.7b**	1.1	**3.4b**	1.3	**3.7c**	1.1	**4.1b**	1.2	**4.5a**	1.1	**4.5ab**	1.2
Performance Approach Goal	**4.4a**	1.1	**4.5a**	1.1	**4.3a**	1.1	**3.8b**	1.3	4.4	1.1	4.5	1.1	4.4	1.1	4.7	1.2
Performance Avoid Goal	**2.7c**	1.1	**2.9bc**	1.1	**3.1ab**	1.1	**3.4a**	1.3	**3.1abc**	1.2	**3.4a**	1.2	**2.7c**	1.2	**3.2ab**	1.3
Achievement[3]																
Final Science Grade	**82.6a**	10.1	**80.2abc**	9.6	**78.0b**	9.6	**73.8c**	12.0	**88.9b**	8.1	**87.7b**	9.1	**88.7b**	7.2	**93.2a**	5.6

Note. Means range from 1 (low) to 6 (high). Means for a dependent variable (row) that are subscripted by different letters and in bold are statistically different (experiment-wise α < .05) computed on an effect identified by ANCOVA. Mean scores for the ANCOVA analyses were adjusted for previous achievement. Superscripts represent separate analyses. Physical Science (n = 392), Life Science (n = 324).

Figure 5. 4-Cluster Solution for Physical Science: Clustering Variables.

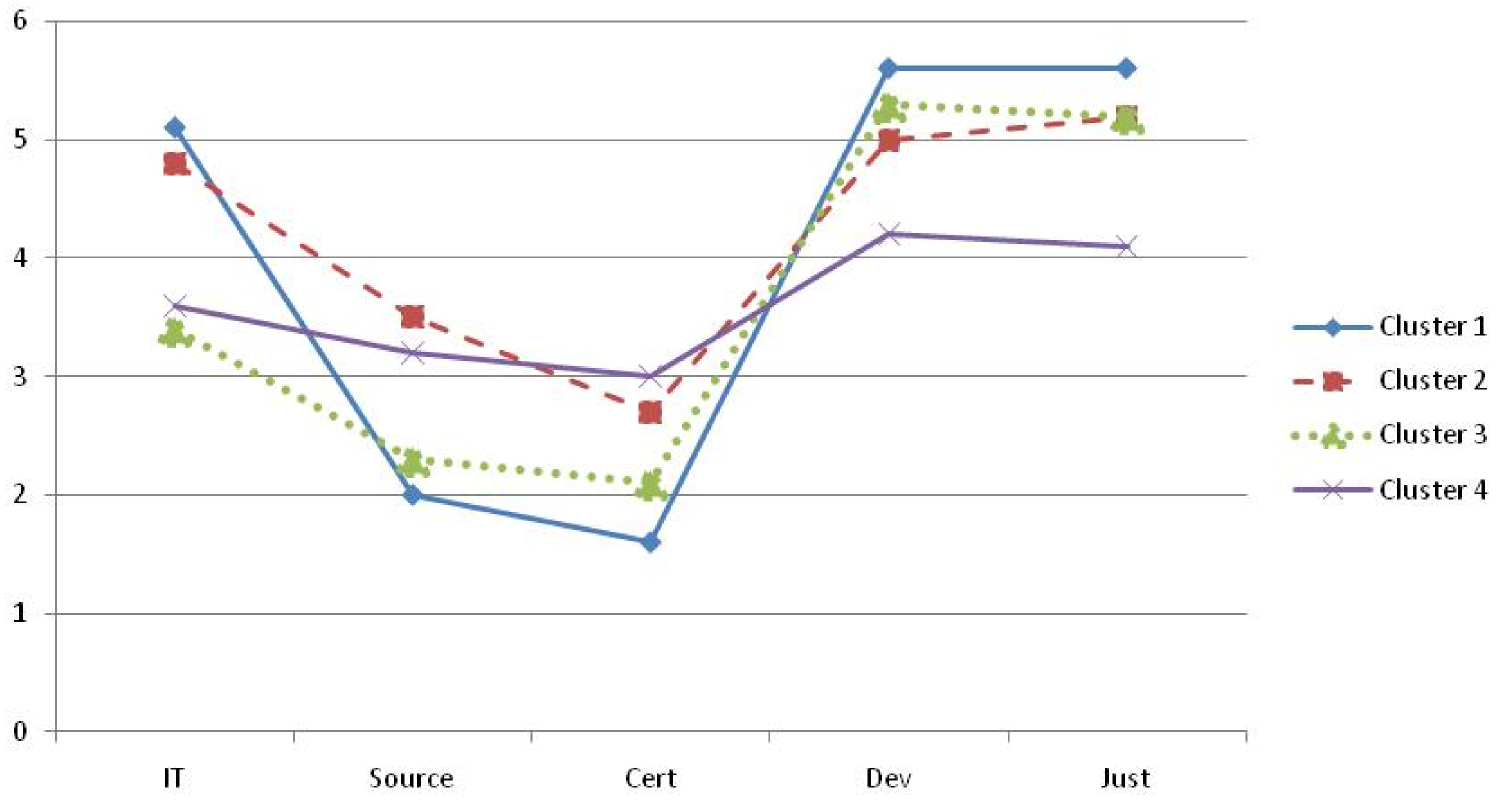
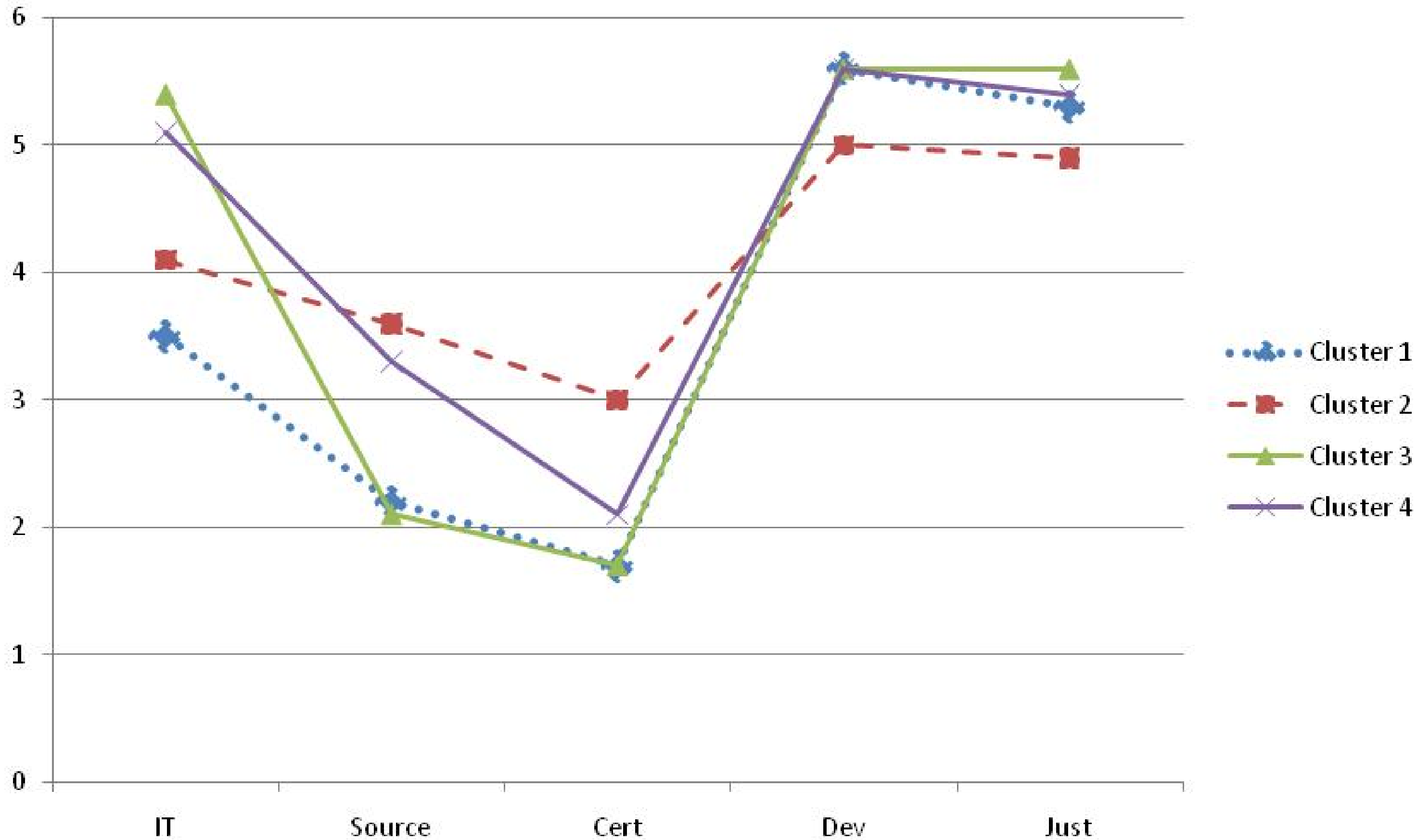


Figure 6. 4-Cluster Solutions for Life Science: Clustering Variables.



overlapped strongly with Clusters 3, 2, and 1 in the life sciences, respectively. Cluster 4 for the two groups was different, which is to be expected. First, I would expect to find differences in profiles between these two groups. Past research suggests that the physical sciences and life sciences differ considerably in their content and, especially in high school, in their emphasis on mathematics. Therefore, differences between these two groups are not surprising. The issue concerning differences between the sciences is discussed in more depth later.

In the next sections, I discuss the profiles in relation to academic motivation and achievement in science. I only discuss the profiles split by school, however, due to a number of possible confounds that may detract from a clearer interpretation of the results. For example, when randomly dividing the full sample in half, each half contains students who come from two different types of schools where the curriculum varies considerably. In addition, each split half contains students taking two different types of science classes. Because the aim of cluster analysis is to form homogenous groups of students, clustering students from two different schools and two types of science class into the same profile may not be appropriate.

With regard to splitting the students by science subject, another possible confound arises. Whereas life science students in the regular public school are in Grade 9, life science students in the charter school are in Grade 10. Physical science students in the regular public school are in Grade 10, but physical science students in the charter school are only in Grade 9. Grouping students into homogenous clusters who are in different grade levels may not be appropriate, especially because Grade 9 marks an important transition from middle school to high school. That is, in the regular public school, life science students are making a major educational transition, whereas in the charter school life science students have already experienced the transition. Finally, whereas all the students in the charter school were either in the honors or gifted track, students in the regular public school came from all tracking levels. And according to the administrators and teachers, the great majority of students in the charter school chose to enroll in the school specifically because they were interested in STEM fields and school subjects. This is quite different from the students enrolled in the regular public school. For these reasons, I examined differences among the profiles split by school. Students in each school are more likely to have similar educational histories and experiences with science. This reduces the amount of within group variance and maximizes the between group variances, which is the intent of creating profiles with Ward's method in cluster analysis.

Question 1: Emergent Student Profiles

Although the *pattern* of the 4-cluster solutions was similar between schools, there were some noteworthy quantitative and qualitative differences with regard to the individual clusters that were formed when split by school. These results are displayed in Table 3 and illustrated graphically in Figures 3 and 4. Below, I discuss characteristics of each profile as they relate to epistemic beliefs and implicit theory of ability.

Regular Public School Profiles

Cluster 1 (Ideal). The 164 students who were classified in the Ideal profile held strong incremental views about their science ability and espoused beliefs about the nature of scientific knowledge that are considered to be more sophisticated stances. Relative to the other three clusters in the regular school, this group of students reported the strongest views about the incremental nature of their science ability (M = 5.2). They also reported the weakest views that scientific knowledge is handed down by an external authority (Source; M = 2.4), and that questions in science only have one correct answer (Certainty; M = 2.0). These students reported relatively strong views that scientific knowledge can change over time (Development; M = 5.4), and that scientific experiments are tools that scientists use to support their arguments and to come up with new ideas (Justification; M = 5.4).

This pattern of beliefs represents relatively sophisticated stances about the nature of scientific knowledge and relatively adaptive views about the nature of intellectual ability. For this reason, this group of students, in terms of beliefs about ability and scientific knowledge, represents what might be considered the *ideal* pattern of beliefs. These students represented the largest group in the regular public school. At the end of the term, this group of students earned a final grade of 86.1, which was significantly higher than all clusters except for the Fixed cluster.

Cluster 2 (Uncommitted). The 37 students who comprised the Uncommitted profile reported moderate views about their epistemic beliefs and implicit theory of ability. Controlling for previous science achievement, this group of students reported statistically significantly weaker views about the incremental nature of science ability compared to students in the Ideal cluster. However, when compared to the other clusters, their implicit theory of ability was not statistically different. Students in this cluster reported relatively moderate views about scientific knowledge coming from an external authority (Source; M = 2.7), and that questions in science have only one correct answer (Certainty; M = 2.8). Students in Cluster 2 did, however, report the weakest views that scientific knowledge constantly evolves (Development; M = 3.9), and that science experiments are not merely projects that are used to demonstrate scientific laws (Justification; M = 3.9).

Therefore, these students believed most strongly that science is a static body of facts that rarely undergoes changes, and that science experiments are merely projects that demonstrate how scientific laws work. On average, these students were relatively *uncommitted* in their stances, reporting only moderate agreement with statements on all variables assessed. This cluster represented the smallest of the four groups. At the end of the term they earned a final grade of 75.1, which was significantly lower than the Ideal and Fixed groups, but not significantly different from the Passive cluster.

Cluster 3 (Passive). There were 113 students who were classified in the Passive profile. These students reported relatively moderate views about the nature of scientific knowledge and the incremental nature of science ability. Specifically, they espoused relatively moderate views that scientific knowledge evolves and can change with new evidence (Development; M = 4.9), and that science experiments are tools that scientists use to support their claims and form new ideas (Justification; M = 4.9). However, with regard to their views about where scientific knowledge comes from, students in this cluster held the strongest views that scientific knowledge can only come from elites like professional scientists (Source; M = 3.8). Also, compared to the other clusters, students in this group held the strongest views that questions in science can only have one correct answer (Certainty; M = 3.2). That is, these students held a relatively *passive* belief that they themselves could not possess the one correct answer for scientific questions. At the end of the term, these students earned a final grade of 80.0, which was not significantly different from any other group's achievement except for that of the Ideal group.

Cluster 4 (Fixed). With 140 students in the Fixed profile, this category represented the second largest group in the regular public school. With respect to their views about the nature of scientific knowledge and knowing, these students were nearly identical to their peers in the Ideal cluster. That is, out of the four clusters, these students, along with those from the Ideal cluster, reported what would be considered the most sophisticated pattern of epistemic beliefs. However, unlike students in the Ideal cluster, students in the Fixed cluster believed more strongly in the fixed nature of science ability. In fact, these students reported significantly lower scores on implicit theory than did students in the Ideal and Passive clusters. They were not, however, significantly different from students in the Uncommitted group. At the end of the term these students earned a final grade of 82.9, which was statistically no different from the grade earned by students of the Ideal group.

STEM Charter School Profiles

Cluster 1 (Incremental). The 83 charter school students who were classified in the Incremental profile endorsed the strongest views about the *incremental* nature of science ability (M = 5.4). These students also reported strong beliefs that scientific knowledge constantly evolves over time (Development; M = 5.6), and that science experiments are tools that scientists use to develop new ideas and bolster their claims (Justification; M = 5.6). Though these views about development and justification represent strong beliefs, relative to the other clusters in the charter school, students in the Incremental cluster were similar to the other groups of students on these measures. The

Incremental students held relatively moderate views about who possesses scientific knowledge (Source; M = 3.1), and that answers in science can have only one correct answer (Certainty; M = 2.0). At the end of the term, students in this cluster earned a final grade of 86.8, which was only significantly higher than students in the Simplistic cluster.

Cluster 2 (Ideal). Students in the Ideal profile reported strong beliefs about the incremental nature of science ability (M = 4.8). In addition, these students reported significantly more sophisticated stances about the Source, Certainty, and Development of scientific knowledge than both the Incremental and Simplistic students. Students in this cluster, however, were statistically equivalent to students in Cluster 4 (Fixed) on these measures. In terms of the overall pattern, these students were similar to the Ideal students from the regular school, and therefore exhibited what would be regarded as an *ideal* pattern of beliefs. Whereas students in the Ideal cluster from the regular school represented the largest cluster, students in the Ideal cluster from the charter school represented the third largest group, with only 70 students. At the end of the term, these students earned a final grade of 87.1.

Cluster 3 (Simplistic). With 94 students in the Simplistic profile, this group of charter school students was the largest. These students reported relatively moderate views about the incremental nature of science ability (M = 4.1). Out of all the clusters represented, students in Cluster 3 reported the most *simplistic* (least sophisticated) views about the Certainty and Development of scientific knowledge. That is, these students held significantly stronger views that there cannot be multiple correct answers to scientific questions (Certainty; M = 2.7). Despite the fact that students in this cluster endorsed the view that scientific knowledge undergoes constant revision (Development; M = 5.0), this score represented the weakest view compared to students from the other clusters. At the end of the term, these students earned a final grade of 82.5, which was significantly lower than that of the Incremental and Ideal groups, but not significantly different from that of the Fixed group.

Cluster 4 (Fixed). This small group of students ($n = 15$) represents a cluster that is nearly identical to the students in the Ideal groups in both the regular and charter schools, with one notable exception. Like the students in the Ideal groups, these students held relatively sophisticated epistemic beliefs. However, unlike students in the Ideal groups, this group of students reported very strong views about the fixed nature of science ability ($M = 2.7$). In fact, out of all the clusters across schools, these students reported the strongest fixed views about the nature of ability. At the end of term, these students earned a final grade of 86.9.

Question 2: Relation of Clusters to Achievement, Motivation, and Interest

Science Achievement and Motivation

The second objective of the present study was to investigate how the emergent profiles related to science achievement and motivation. These results are displayed below in Table 5 and illustrated graphically in Figures 7 and 8. Note that for science motivation, I compared mean differences between clusters while controlling for prior achievement. By doing so I was able to focus on differences in cluster membership due to the variance in motivation variables and diminish the prior achievement confound.

Regular school – Ideal group. Recall that students in the Ideal profile displayed the most sophisticated epistemic beliefs as well as the strongest views about the incremental nature of ability. As hypothesized by Dweck and Leggett (1988) and those

Table 5. *Means and Standard Deviations for Motivation Variables in the Study by School and Cluster.*

	REGULAR PUBLIC SCHOOL								STEM CHARTER SCHOOL							
	Cluster 1 (Ideal) (n = 164)		Cluster 2 (Uncommitted) (n = 37)		Cluster 3 (Passive) (n = 113)		Cluster 4 (Fixed) (n = 140)		Cluster 1 (Incremental) (n = 83)		Cluster 2 (Ideal) (n = 70)		Cluster 3 (Simplistic) (n = 94)		Cluster 4 (Fixed) (n = 15)	
Variables	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
Motivation[1]																
Self-Efficacy	**5.2a**	1.1	**4.7bc**	1.3	**5.0ab**	1.2	**4.6c**	1.0	**5.2a**	0.9	**5.0ab**	0.9	**4.9b**	0.9	**4.3c**	0.9
SE for Self-Regulation	**4.3a**	1.0	**3.9b**	1.2	**4.1ab**	1.1	**3.9b**	1.0	**4.5a**	0.9	**4.2b**	0.9	**4.1bc**	0.9	**3.5d**	0.9
Self-Concept	**4.5a**	1.1	**3.3d**	1.3	**4.1b**	1.2	**3.7c**	1.1	**4.5ab**	1.0	**4.1c**	0.9	**4.2bc**	1.0	**3.5d**	0.9
Mastery Goal	**4.1a**	1.2	**3.5b**	1.4	**3.8b**	1.3	**3.5b**	1.1	**4.8a**	1.0	**4.7a**	0.9	**4.3b**	1.0	**3.6c**	0.9
Performance Approach Goal	**4.5a**	1.1	**3.7b**	1.3	**4.4a**	1.2	**4.2ab**	1.1	4.6	1.2	4.4	1.1	4.6	1.2	4.4	1.1
Performance Avoid Goal	**2.7b**	1.2	**3.1ab**	1.4	**3.2a**	1.3	**3.0a**	1.1	**3.0ab**	1.2	**2.8b**	1.1	**3.3a**	1.2	**3.2ab**	1.2
Achievement[2]																
Final Science Grade	**86.1a**	9.2	**75.1c**	13.7	**80.0bc**	13.2	**82.9ab**	10.3	**86.8a**	8.8	**87.1a**	8.8	**82.5b**	9.1	**86.9ab**	8.0

Note. Means range from 1 (low) to 6 (high). Means for a dependent variable (row) that are subscripted by different letters and in bold are statistically different (experiment-wise α < .05) computed on an effect identified by ANCOVA. Mean scores for the ANCOVA analyses were adusted for previous achievement. Superscripts represent separate analyses. Regular (n = 454), Charter (n = 262).

Figure 7. Relation of Clusters to Motivation Variables: Regular Public School.

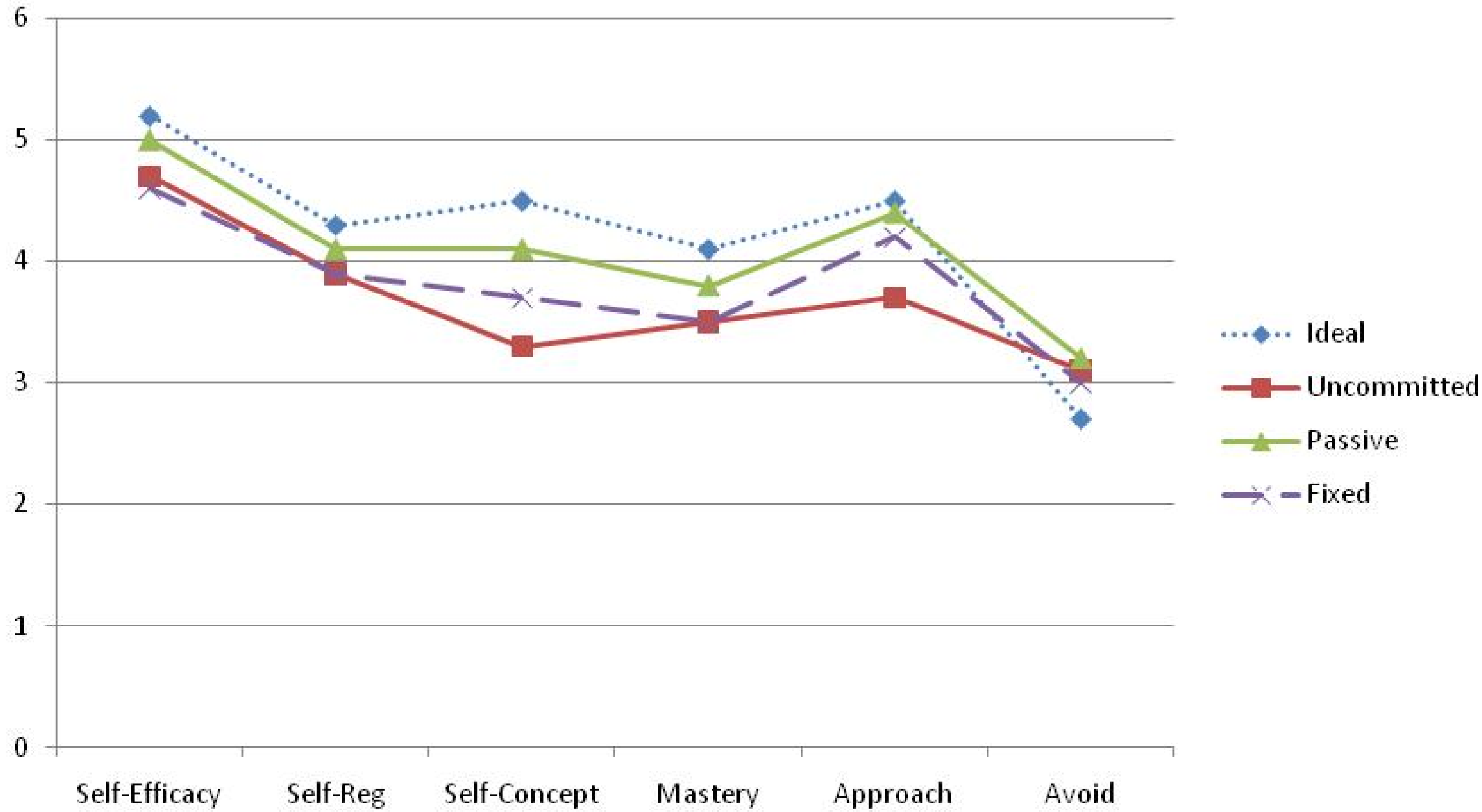
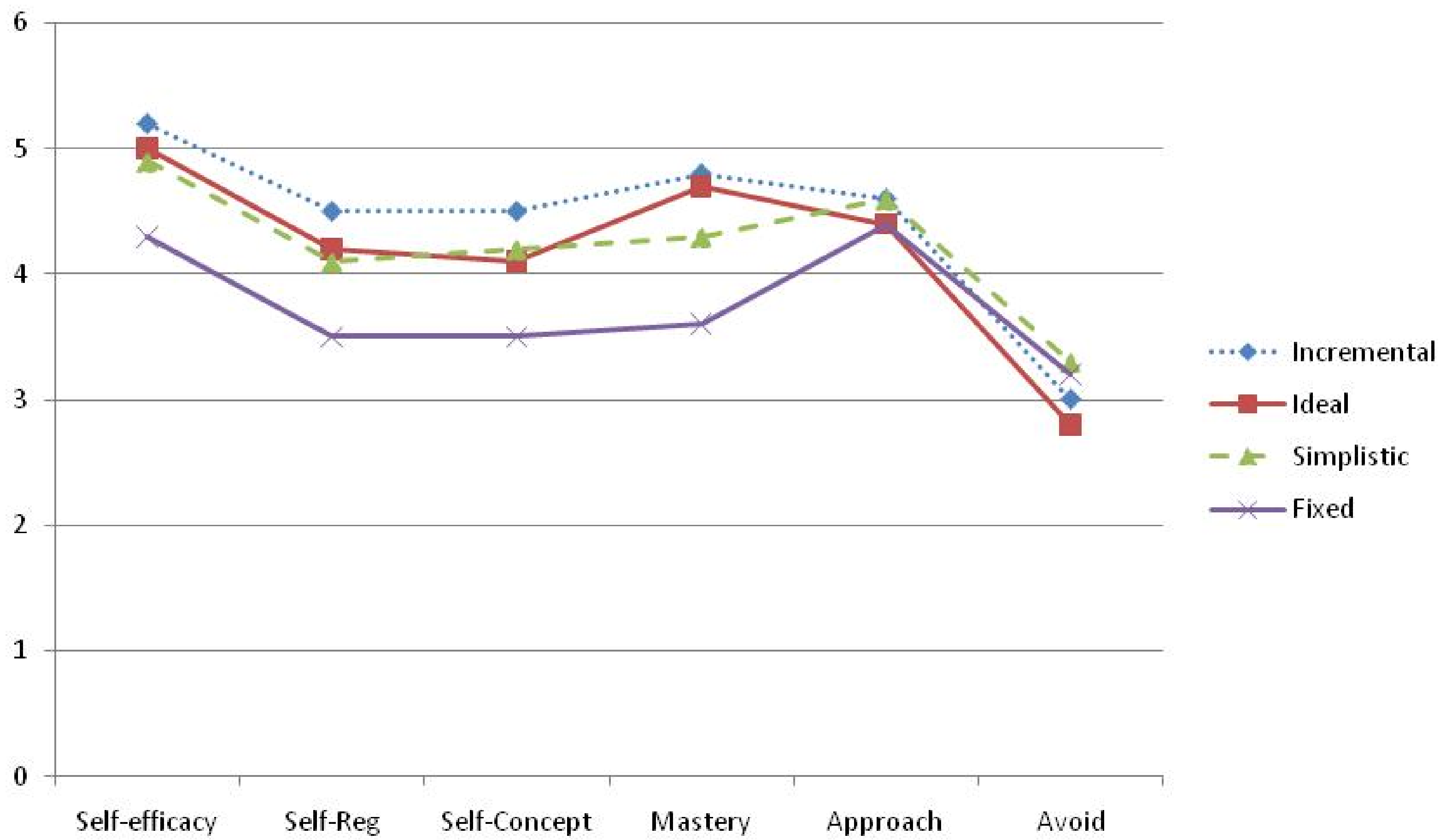


Figure 8. Relation of Clusters to Motivation Variables: Charter School.



who research epistemic beliefs, these adaptive views about the nature of ability and the nature of knowledge also were associated with the most adaptive motivational beliefs. These students reported that they were very confident in achieving high science grades (self-efficacy; M = 5.2) and in regulating their work and study habits (self-efficacy for self-regulation; M = 4.3). Compared to students in the other clusters, students in the regular school's Ideal group also held the most positive views about themselves with regard to science (self-concept; M = 4.5). They also tended to approach tasks with the intention of learning the material (mastery goal orientation), but were also concerned with appearing smart in front of others (performance approach goal orientation), and not concerned with embarrassing themselves in front of others (performance avoid goal orientation).

These Ideal group students received significantly higher science grades at the end of the term compared to students in the Uncommitted and Passive groups, but were not significantly different from students in the Fixed group. These findings support past empirical results that show incremental views of ability and more sophisticated stances about the nature of knowledge and knowing are associated with adaptive patterns of motivation and higher achievement.

Regular school – Uncommitted group. Recall that students in the Uncommitted profile expressed moderate views about the incremental nature of ability, the development of scientific knowledge, and the purpose of scientific experiments. Also recall that this group of students reported the weakest views about the source and certainty of knowledge. These students reported relatively low levels of science motivation across all variables assessed. Most notably, they had the most negative views about themselves in science (Self-Concept; M = 3.3).

These findings support past empirical results showing that weaker views about the incremental nature of ability are associated with maladaptive patterns of motivation and lower achievement. Also, despite having moderate views about the source and certainty of knowledge, these students' very weak endorsement of the development and justification of knowledge were related to their less adaptive science motivation and lower achievement.

Regular school – Passive group. As mentioned earlier, the regular school students in the Passive profile held the strongest views that scientific knowledge can only come from an external authority, and that questions in science can only have one correct answer. Across the other three clustering variables, these students expressed relatively moderate views. These moderate views of scientific knowledge and ability were related to this group's relatively moderate science motivation as well. Statistically, these students were less confident than their peers in the Ideal group at achieving high grades in science and at regulating their work and study habits. However, they were no different on these variables from their peers in the other groups. They held relatively positive views about themselves in science (Self-concept; M = 4.1). Finally, they held relatively moderate mastery and performance goal orientations.

This moderate pattern of beliefs and motivation was associated with average science achievement. The pattern of beliefs these students reported supports past empirical evidence that epistemic beliefs are multidimensional and more or less independently functioning. These students possessed both relatively adaptive and relatively maladaptive views about scientific knowledge. As hypothesized by Buehl and Alexander (2005), relatively maladaptive beliefs about the source of knowledge may not be associated with poorer performance, especially if accompanied by more adaptive beliefs in other dimensions. With this particular group of students, a strong belief about knowledge coming from an external source was accompanied by relatively adaptive beliefs about the development and justification of knowledge.

Regular school – Fixed group. Recall that the regular school students in the Fixed profile reported very adaptive stances on all four of the epistemic belief dimensions. However, compared to the other three clusters, these students held the weakest views about the incremental nature of ability. The predictions for this group of students are mixed. On the one hand, past empirical evidence would lead one to believe that highly sophisticated beliefs about the nature of scientific knowledge would translate into strong science motivation and achievement. On the other hand, Dweck and Leggett (1988) would predict that more fixed views about science ability would set these students up for a pattern of maladaptive motivation beliefs and poorer achievement.

In fact, this is precisely what I found. As predicted by Dweck and Leggett, despite these students' relatively adaptive epistemic beliefs, their weak views about the incremental nature of ability were related to lower levels of science motivation. Compared to students in the Ideal and Passive groups, students in the Fixed group reported lower confidence in doing well in science, but were not significantly less self-efficacious than students in the Uncommitted group. They also reported significantly weaker views about approaching science tasks with the purpose of mastering the concepts than those from the Ideal and Passive groups. However, despite their lower motivation and fixed views of ability, they still performed quite well academically.

Charter school – Incremental group. Although students in the Incremental profile expressed moderate views about scientific knowledge coming from an external authority, their source views were more naïve *compared to* students in the other groups. As hypothesized by Dweck and Leggett (1988), these students' high incremental beliefs about science ability were in fact related to overall strong science motivation. Also, as hypothesized by Buehl and Alexander (2005), relatively maladaptive source beliefs, when accompanied by relatively adaptive epistemic beliefs in other dimensions, may not be related to a detriment in motivation or achievement. Students in this cluster were significantly more confident in regulating their work and study habits than students from any other group. These students were also significantly more confident at doing well in science than their peers in the Simplistic and Fixed groups, but were not significantly more self-efficacious than their peers in the Ideal group. They also had significantly more positive views about themselves in science than their peers in the Ideal or Fixed groups. They also approached science tasks with the intent of mastering the material and appearing smart in front of others.

Charter school – Ideal group. As mentioned earlier, similar to their peers in the Incremental group, the students in the Ideal group expressed strong views about the incremental nature of ability. They also exhibited sophisticated stances across all four dimensions of epistemic beliefs. These stances about the nature of scientific knowledge, combined with strong incremental beliefs about ability, were related to high science achievement and adaptive motivational beliefs.

Charter school – Simplistic group. Recall that students in the Simplistic profile reported the least sophisticated stances across all four epistemic belief dimensions. These students also reported moderate views about the incremental nature of ability. As hypothesized, these students, who represented the largest group in this school, reported moderate levels of science motivation and lower science achievement than students from the Incremental and Ideal groups. Although, readers would do well to keep this achievement in perspective, because these students still earned good grades (M = 82.5).

Charter school – Fixed group. Recall that the students in the Fixed profile reported sophisticated epistemic beliefs across all four dimensions, similar to their peers in the Ideal group. However, these students expressed the weakest views about the incremental nature of science ability out of all students across schools. Like the Fixed group of the regular school, these charter school students exhibited a similar profile. However, whereas the Fixed group in the regular school was large, this group of charter school students was the smallest in the school (n = 15).

Similar to the students in the regular school, despite these charter school students' sophisticated views about science, they reported weak levels of science motivation. Specifically, they were the least confident of all their peers in the charter school at performing well in science and in regulating their work and study habits. They also had the most negative views about themselves with regard to science.

Interest in Pursuing a STEM Career

Table 6 shows the frequency of students for each cluster expressing an interest in pursuing the following four types of occupations, split by school: 1) STEM career requiring a 4-year degree; 2) STEM career not requiring a 4-year degree; 3) Non-STEM career requiring a 4-year degree; and 4) Non-STEM career not requiring a 4-year degree. This table also includes the rating for how confident students were about pursuing the indicated career. Table 7 shows how many STEM jobs students in each cluster listed as ones they realistically saw themselves pursuing. Recall that each student could list up to three occupations. This table also includes a ratio of STEM jobs listed per student. Overall, despite the differences between clusters on the motivation and achievement variables, there were no significant differences among clusters as a function of students' interest in pursuing a STEM career for either school.

Question 3: Relation of Clusters to Demographic and Contextual Factors

The third and final objective of the present study was to explore how the emergent student profiles differed with respect to race/ethnicity and gender. I also wanted to explore how these profiles differed by science class taken (life versus physical science) and by tracking level (gifted versus regular track). The results of the chi-squared tests of independence appear on Tables 8 and 9. Because there were no significant differences between the clusters as a function of gender or of science class for either of the schools, the discussion below focuses specifically on differences by race/ethnicity and by gifted status.

Race/ethnicity. For the regular school, I found significant differences between the clusters as a function of race/ethnicity [χ^2 (9, N = 410) = 21.08, p<.05]. Specifically, there were more White students represented in the Ideal cluster than would be expected by chance and there were fewer White students represented in the Passive cluster than would be expected by chance. For the charter school, however, there were no significant differences as a function of race/ethnicity [χ^2 (9, N = 249) = 16.30, p = .06]. These results support the hypothesis that more non-White students would be represented in profiles that exhibited less sophisticated views about scientific knowledge.

Gifted status. For the regular school, there were significant differences found between the clusters as a function of gifted status [χ^2 (3, N = 454) = 35.32, p<.001]. There were more students enrolled in the gifted program in the Ideal and Fixed clusters than would be expected by chance. There were more students not enrolled in the gifted program in the Uncommitted and Passive groups than would be expected by chance. For the charter school, there were also significant differences found between the clusters as a function of gifted status [χ^2 (3, N = 262) = 11.90, p<.01]. Specifically, there were more students enrolled in the gifted program in the Ideal and Incremental groups than would be expected by chance. There were more students not enrolled in the gifted program in the Simplistic group than would be expected by chance. These results support the hypothesis that sophisticated beliefs about science are associated with higher academic performance.

Table 6: Frequencies and Confidence of Students' Career Aspirations for Regular versus Charter School.

	STEM Interest/ 4-Yr. Degree			STEM Interest/ No 4-Yr. Degree			No STEM Interest/ 4-Yr. Degree			No STEM Interest/ No 4-Yr. Degree		
	Frequency	%	Confidence	Frequency	%	Confidence	Frequency	%	Confidence	Frequency	%	Confidence
REGULAR SCHOOL												
Ideal	79	48.2	5.1	2	1.2	4.5	51	31.1	4.9	32	19.0	5.0
Uncommitted	12	32.4	4.5	4	10.8	4.5	6	16.2	5.2	15	40.5	5.0
Passive	48	42.5	5.0	2	1.8	4.5	25	22.1	4.9	38	33.6	5.0
Fixed	53	37.9	4.7	4	2.9	5.8	35	25.0	5.2	48	34.3	4.8
CHARTER SCHOOL												
Incremental	74	89.2	4.9	0	0.0	n/a	7	8.4	4.3	2	2.4	5.0
Ideal	55	78.6	4.9	1	1.4	6.0	8	11.4	4.8	6	8.6	5.5
Simplistic	81	85.1	4.8	2	2.1	5.0	8	8.5	4.5	3	3.2	4.0
Fixed	10	66.7	4.8	0	0.0	n/a	3	20.0	4.3	2	13.3	4.0

Note . Confidence refers to how confident students reported they were in pursuing the career they indicated as the one they most wanted to pursue. Mean ranges from 1 (low) to 6 (high).

Table 7: *Frequencies of STEM Jobs Listed for Regular and Charter School Students.*

	STEM Interest/ 4-Yr. Degree			STEM Interest/ No 4-Yr. Degree			No STEM Interest/ 4-Yr. Degree			No STEM Interest/ No 4-Yr. Degree			CLUSTER TOTALS		
	Frequency STEM Jobs Listed	n	Ratio	Frequency STEM Jobs Listed	n	Ratio	Frequency STEM Jobs Listed	n	Ratio	Frequency STEM Jobs Listed	n	Ratio	Frequency STEM Jobs Listed	n	Ratio
REGULAR SCHOOL															
Ideal	177	79	**2.2**	1	2	**0.5**	28	51	**0.5**	27	32	**0.8**	233	164	**1.4**
Uncommitted	28	12	**2.3**	7	4	**1.8**	5	6	**0.8**	4	15	**0.3**	44	37	**1.2**
Passive	97	48	**2.0**	3	2	**1.5**	15	25	**0.6**	22	38	**0.6**	137	113	**1.2**
Fixed	113	53	**2.1**	6	4	**1.5**	17	35	**0.5**	23	48	**0.5**	159	140	**1.1**
CHARTER SCHOOL															
Incremental	177	74	**2.4**	0	0	**n/a**	7	7	**1.0**	1	2	**0.5**	185	83	**2.2**
Ideal	131	55	**2.4**	1	1	**1.0**	2	8	**0.3**	4	6	**0.7**	138	70	**2.0**
Simplistic	208	81	**2.6**	6	2	**3.0**	9	8	**1.1**	4	3	**1.3**	227	94	**2.4**
Fixed	24	10	**2.4**	0	0	**n/a**	1	3	**0.3**	3	2	**1.5**	28	15	**1.9**

Note . Ratio refers to the mean number of STEM jobs listed for every student. Students were able to indicate up to three jobs they were interested in pursuing.

Table 8: *Frequencies of Cluster Membership by Race/Ethnicity for Regular Public School .*

	ASIAN		WHITE		BLACK		HISPANIC	
	Frequency (Expected)	%	Frequency (Expected)	%	Frequency (Expected)	%	Frequency (Expected)	%
REGULAR SCHOOL								
Ideal	27 (30.7)	6.6	84 (70.8)	20.5	23 (26.9)	5.6	9 (14.6)	2.2
Uncommitted	7 (7.3)	1.7	13 (16.8)	3.2	9 (6.4)	2.2	5 (3.5)	1.2
Passive	30 (22.3)	7.3	35 (51.5)	8.5	23 (19.5)	5.6	16 (10.6)	3.9
Fixed	24 (27.7)	5.9	71 (63.9)	17.3	22 (24.2)	5.4	12 (13.2)	2.9

Table 9: *Frequencies of Cluster Membership by Gifted Status for Regular and Charter School Students.*

	GIFTED		NON-GIFTED	
	Frequency (Expected)	%	Frequency (Expected)	%
REGULAR SCHOOL				
Ideal	68 (53.1)	15.0	96 (110.9)	21.2
Uncommitted	1 (12)	0.2	36 (25.0)	7.9
Passive	21 (36.6)	4.6	92 (76.4)	20.3
Fixed	57 (45.3)	12.6	83 (94.7)	18.3
CHARTER SCHOOL				
Incremental	65 (60.5)	24.8	18 (22.5)	6.9
Ideal	58 (51)	22.1	12 (19.0)	4.6
Simplistic	57 (68.5)	21.8	37 (25.5)	14.1
Fixed	11 (10.9)	4.2	4 (4.1)	1.5

CHAPTER 5

DISCUSSION

A long line of research has shown that students who believe that their intellectual ability can be expanded tend to exhibit more adaptive patterns of motivation and achieve higher grades than do those who believe that their intellectual ability is static. The results of the study partially support past variable-centered work showing that incremental views of ability are related to higher motivation. For example, in both schools, the Ideal group's stronger incremental beliefs about ability were related to more adaptive self-efficacy, self-regulatory beliefs, self-concept, and mastery and performance avoid goal orientations. However, in both schools, this incremental view of ability did not relate to higher achievement. Therefore, although an incremental view was related to increased motivation, in the case of these two groups, there were no differences with regard to achievement.

Researchers have also begun to show that students' beliefs about the nature of knowledge and the process of knowing are related to academic motivation and achievement. The results of the study partially support past variable-centered work demonstrating the motivational and achievement benefits of more sophisticated epistemic beliefs. For example, in the regular school, the Uncommitted and Fixed groups both exhibited similar implicit theories of ability. However, the Uncommitted group reported less sophisticated beliefs about scientific knowledge than did the Fixed group. This difference between the two profiles was related to lower grades and lower self-concept. These less sophisticated views of scientific knowledge, though, were not related to less adaptive self-efficacy, self-regulatory beliefs, or goal orientations. I propose possible reasons for this discrepancy in more depth in the limitations section below.

Researchers using the variable-centered approach have produced much empirical evidence supporting the motivational and achievement benefits of incremental views of ability and sophisticated views about knowledge. However, the literature is less developed as it relates to how these beliefs might interact and configure with each other to influence the motivation and achievement outcomes of high school science students. Below, I discuss theoretical and practical implications of creating student profiles from clusters of variables.

Clustering Variables to Form Profiles: Theoretical Implications

Single variables do not act alone. Pintrich (2003) argued that researchers would benefit from investigations that explore how variables configure together to produce motivated patterns of behavior rather than to pit one variable against others to see which one has the best explanatory power. With the gaining popularity of clustering techniques to identify profiles or subcommunities within a sample, researchers are beginning to explore the profiles of students that arise naturally with measures of epistemic beliefs. And although there is wide consensus that epistemic beliefs and implicit theories of ability are indeed two separate constructs, it is quite possible that these two beliefs operate independently and in conjunction with each other within individual students. Therefore, cluster analytic techniques are an attractive method to test this hypothesis—that beliefs about knowledge and knowing and beliefs about ability, though separate constructs, might configure to form unique profiles of students.

The results of the study support the idea that there are multiple subcommunities of students within science classrooms, and that these subcommunities are related to differential patterns of motivation and achievement. Four profiles emerged within both the regular public school and the STEM charter school. These results are consistent with the only other empirical study that has explored students' epistemic belief profiles (see Buehl & Alexander, 2005) and their relations to motivation and achievement. Like Buehl and Alexander, I found groups of students who held adaptive beliefs about science across all epistemic belief dimensions as well as students who held a mixture of adaptive and maladaptive beliefs. However, because I included implicit theories of ability in forming the clusters, my results build on the work of Buehl and Alexander, as described below.

When considering epistemic beliefs in relation to student motivation and achievement in science, it seems particularly important to include implicit theories of ability. Compare, for example, the Ideal and the Fixed groups in both schools. Although students in both profiles exhibited sophisticated beliefs about the nature of scientific knowledge, the Ideal group had significantly more adaptive self-efficacy, self-regulatory beliefs, self-concept, and mastery goal orientations. Although no causal claims can be made, this difference in motivation seems to be related to the significant difference in their beliefs about intellectual ability. What is perhaps most alarming is the fact that these two groups of students did not differ in achievement. Therefore, one of the most common and ostensible measures used as a proxy to assess whether someone is suited for STEM careers—science achievement—does not seem sufficient, especially in light of the fact that my analyses were conducted controlling for previous achievement.

Results of this study refine the theoretical framework that undergirds the work in epistemic beliefs. Hofer and Pintrich (1997) suggested that, in an effort to keep the construct conceptually clean, beliefs about the nature of knowledge and knowing should be kept separate from beliefs about intellectual ability. At the same time, Schommer-Aikens (2004), breaking from her original conception that beliefs about ability should be considered one dimension of epistemic beliefs, posited an Embedded Systemic Model. In this model, Schommer-Aikens argued that although these two beliefs are different constructs, they may interact with each other. This implies that implicit theories cannot be excluded from consideration when thinking about epistemic beliefs in relation to motivation and achievement. My results support this notion. The belief that people are either good or poor at science should be considered alongside beliefs about the nature of science. Although these two beliefs may in fact be separate constructs, implicit theories of ability appear to be important enough to students' motivation and achievement that they cannot be ignored when investigating epistemic beliefs.

Clustering Variables to Form Profiles: Practical Implications

There are practical implications for these results as well. Teachers who encourage their students to refine their beliefs about the nature of scientific knowledge may be facilitating their students' understanding of the epistemological assumptions of science. But if they do not also address students' beliefs about their intellectual abilities, their students' motivation to pursue STEM related fields may not benefit, even while their grades are quite good. The current push in science education reform to teach students about the nature of science may facilitate students' competence in understanding and doing science. However, for adolescents to seek out these types of careers and persist through difficulties, they need to be both competent and confident in science. In fact, Bandura (1997) argued that

> people often forsake realizable challenges because they believe they require extraordinary aptitude … People see the extraordinary feats of others but not the unwavering commitment and countless hours of perseverant effort that produced them. Such partial information generally leads people to overestimate inherited endowments and underestimate self-regulatory factors in human accomplishments. (p. 119)

Therefore, teachers would do well to emphasize the incremental nature of ability and the self-regulatory processes like hard work and effective strategies that are the hallmark of those who succeed, in addition to teaching students about the epistemological assumptions of science.

Investigating science beliefs using a person-centered approach also provides another advantage. Cluster analytic techniques are a common tool used in analyzing commercial markets. In market analysis research, economists typically try to identify different sectors of the market in an effort to cater advertisements to these different profiles of consumers. In a similar fashion, viewing students in a science classroom in terms of profiles made up of beliefs about the nature of knowledge and the nature of science ability may help educators design specific interventions to help improve their students' understanding and interest in science. For example, for the Fixed students who already hold an adaptive pattern of epistemic beliefs, teaching them about the nature of scientific knowledge may prove futile in a teacher's effort to encourage participation in STEM careers. What is more likely to be beneficial for these students are messages directed toward their students' ability to improve their science "smarts" by enlisting the appropriate strategies and effort.

For students in the Uncommitted group a different approach might be necessary. Despite their similarity to Fixed students on the implicit theory measure, Uncommitted students held particularly maladaptive views about the development and justification of scientific knowledge. They also achieved lower grades and reported lower levels of science self-concept. Although it is difficult if not impossible to propose a specific intervention, Uncommitted students may be struggling with science because their epistemological assumptions about science might not be congruous with the ways in which the traditional science curriculum is portrayed. This is especially salient given that within this Uncommitted group, there was an overrepresentation, albeit slight, of students who are traditionally marginalized in science fields. Also, students enrolled in the gifted program were highly underrepresented in the Uncommitted group. I discuss issues of race/ethnicity and tracking level in greater detail below. Clearly though, Uncommitted students require science instructional interventions that are different from those who are in the Fixed group.

Profiles by Race/Ethnicity, Gender, and Gifted Status

In addition to exploring the profiles that naturally emerged and their relations to science motivation and achievement, another purpose of the study was to explore how these emergent profiles differed with respect to demographic factors like race/ethnicity and gender and contextual factors like tracking level. Based on previous empirical work, I hypothesized that Asian and Hispanic students would be overrepresented in profiles with less sophisticated Source beliefs and Hispanic students would be overrepresented in profiles with less sophisticated Certainty beliefs. The results of the present study support my hypotheses. In the present study, there were more Asian students in the Passive group, which exhibited strong beliefs about scientific knowledge coming from an external authority and that questions in science only have one right answer. This finding is in line with results from others who have indicated that Asian students are more likely to place a strong emphasis on knowledge from external authorities (e.g., Chan & Elliott, 2002).

One major caution is in order. Calling certain beliefs naïve or unsophisticated is a product of Western thought (Hofer, 2008). Different cultures have different standards by which to judge a belief as sophisticated or not. Some have also shown that beliefs about intelligence are culturally bound (Sternberg, 2006; Sternberg & Grigorenko, 2004). As Luykx et al. (2007) rightly argued,

> all students bring to the learning process their own ways of interpreting the natural and social worlds, acquired from their cultural environments, discursive traditions, and personal circumstances. For 'Mainstream' children (i.e., White, middle-class, native English speakers), the linguistic and cultural knowledge they acquire at home is largely continuous with the expectations and assumptions of the school. … At the same time, some children's linguistic and cultural traditions may be inconsistent with the scientific orientation toward knowledge, the nature of specific scientific disciplines, or the ways in which science disciplines are taught in school. Such inconsistencies may create difficulties for students learning science and for the teachers trying to teach them. (p. 899)

No doubt, the cultural funds of knowledge (Moll, 1992; Vélez-Ibánez, 1992) that students bring to their science classes affect the ways in which they view science and their abilities to do science as it is presented in their classrooms. For this reason, teachers would do well to explicitly teach students the epistemological assumptions that underlie the science subjects they teach. And rather than pejoratively labeling cultural values such as placing considerable trust in authoritative sources as naïve or unsophisticated, reconciling differences meaningfully with students who come to science classes unaware of the traditional Western scientific epistemologies may help students understand science and their own relationship to it.

With regard to tracking level, I hypothesized that students in the gifted level science classes would be overrepresented in profiles exhibiting more sophisticated epistemic beliefs. This hypothesis was supported in the present study. Students in the gifted program were overrepresented in the Ideal and Fixed profiles in the regular school, both of which represented groups exhibiting sophisticated views about scientific knowledge. Noteworthy with the regular school is the fact that the Fixed profile was overrepresented by gifted students. Despite their sophisticated understandings about the nature of science, these students did not believe that their science abilities were increasable. From the perspective of science educators, this may be cause for alarm. Despite the efforts of educators to facilitate a more sophisticated view of scientific inquiry, if students' beliefs about the incremental nature of their ability are not targeted, these efforts may not motivate and encourage more students to pursue STEM fields. Therefore, a sophisticated view of the nature of scientific inquiry may be a necessary, but not a sufficient, part of generating interest in these careers.

If implicit theories of ability had not been grouped with the four dimensions of epistemic beliefs, these Fixed students would have been categorized as sophisticated learners. As a result, I would have missed the fact that within this group of sophisticated learners there are some who simply believe their science abilities are too limiting for them to pursue STEM careers. This is particularly problematic because these students are likely quite capable of doing well in science related careers. They achieved high grades and many of them were enrolled in the gifted program, which means that they had to score in the 96th percentile on tests of academic ability. Furthermore, they seem to have a sophisticated understanding of the nature of science. Despite all this, however, students in this Fixed group exhibited significantly lower motivation. Specifically, students in this profile attending the charter school showed significantly lower self-efficacy, self-regulatory beliefs, self-concept, and mastery goal orientations than did their peers in other profiles. Students in this profile in the regular school exhibited low self-efficacy, self-regulatory beliefs, and mastery goal orientations, though not significantly lower than their peers in the Uncommitted group. Although many policy makers and politicians argue that encouraging students to pursue STEM careers is a national economic imperative, it seems that for these students the issue at hand is more about the significant waste and underutilization of talent. This is particularly relevant considering the fact that of the 140 regular school students in this group, 57 of them (41%) were students in the gifted program.

One note should be made, however. Although the present study is person-centered the patterns may reduce the amount of complexity and diversity that could still exist even within one profile. It is possible, for example, that there are some students in this Fixed profile who benefit from espousing a fixed view of ability and others who are constrained by this belief. Although Dweck and her colleagues portray the fixed view of ability as resulting in maladaptive beliefs and behaviors, it may be possible that some students benefit. For example, some students may achieve very high grades. And because they believe their high achievement is a result of their intellectual gifts, they may continue to perform well and experience a number of motivational benefits, including high self-efficacy and self-concept. Future investigations could explore this possibility.

As for gender differences, the results of the present study did not confirm my hypothesis that there would be an overrepresentation of boys in profiles with stronger incremental views of ability. Although Dweck (1999) has argued that girls, especially high achieving girls, are especially likely to view ability as a static entity, my findings do not support this claim. This finding may be an encouraging sign illustrating that gender differences in science are not as stark as they may have been in the past. This is especially so considering the fact that the students in the present study were in high school, which is a time when girls are more likely to display less adaptive views about their ability (Dweck, 2002).

One reason, however, why I may not have detected any gender differences is that the profiles were formed based on both biological and physical sciences. As explained earlier, the reason I did not form profiles separated by science subject is that there were a number of confounds that may have reduced interpretability. However, even though this is beyond the scope of the present study, I did find that in the physical sciences, the profile that exhibited sophisticated epistemic beliefs but weak incremental beliefs (Cluster 3) was overrepresented by girls. However, in the life sciences, there were no significant differences in gender. This suggests that in science subjects that are considered more mathematics intensive (e.g., physics or chemistry) girls may be less confident about the incremental nature of their ability. Because much of the work Dweck and her colleagues have done to investigate gender differences has been done in mathematics classrooms, this finding corroborates her past empirical results. However, future cluster analytic work should be done to investigate this issue with more homogenous groups or with a much larger sample of students.

Differences Between Schools

The STEM charter school was designed to attract students who expressed an interest in STEM careers and fields. Each year the school sends application materials to all middle schools in the county. Included in this application is a notice that parents and students should view the information included called Indicators of Success. This table lists ranges of test scores on standardized tests for students who have previously been successful in the school. For example, parents and students are informed that successful students in the past have typically scored in the 89th percentile for the Grade 8 Mathematics Iowa Test of Basic Skills (ITBS). Another statistic indicates that students who have scored at least 120 on the Cognitive Abilities Test (CogAT) have been successful in the school.

For this reason, it is not surprising to see that in the charter school the variability in achievement within and between profiles was less than that of the regular public school. Therefore, in terms of achievement, the students in the charter school were much more homogenous than the students in the regular public school. And despite what would be regarded as an explicit linking of high test scores to success on the information pamphlet, students in the charter school did not report, on average, strong fixed views of ability (Mean Implicit Theory Score = 4.6). Also, despite the small amount of variance in grades, the profiles and the associated differences in motivation still emerged. This suggests that the beliefs students hold both about themselves and the world around them can be just as influential on academic outcomes as previous achievement.

Another interesting finding concerns the relative size of the Fixed group in both schools. The Fixed group of the regular public school was the second largest. In fact, of the 454 students in this school 140 (30.8%) of them fell into this group. However, in the STEM charter school, out of the 262 students in this school, only 15 (5.7%) fell into this group. Although the data collected cannot speak to the underlying reasons for why this may be, I propose one possible explanation. The charter school, as mentioned above, attracts students who have an interest in STEM subjects and want to pursue a STEM career. The charter school also overtly advertises to potential applicants that typically those who have performed well in school in the past and who have scored well on standardized tests are likely to fit well into the charter school. The self-selection of students is probably limited, then, to those students who are highly motivated to do science. Because the students who showed the lowest motivation were those who were in the Fixed profile, the number of applying students who might be categorized in this profile is likely dramatically lower than what is seen in the regular public schools.

Limitations and Future Directions

A salient limitation of the present study lies in the nature of the self-report instruments used to assess the self-beliefs constructs. These traditional approaches present individuals with lists of statements to which they are asked to respond that may or may not correspond to the beliefs relevant to their perceived reality and may fail to accurately reflect their unique perceptions and feelings (Munby, 1984). Furthermore, the instruments serve to operationalize the constructs under investigation, and so construct validity is always a reasonable concern. This issue may be of particular concern with measures of epistemic beliefs, because these beliefs are so implicitly held that students might well be unaware of what they actually believe about the nature of knowledge and knowing (Hofer & Pintrich, 1997; Karabenick et al., 2007). Nevertheless, to ensure that students answered with care and honesty, students were assured that their answers would remain confidential and that only aggregate data would be reported.

Because I used a survey instrument, the responses that students provided were done so under a framework that was provided by outside forces (an *etic* perspective). In the future, researchers may explore what meaning these items actually provoke in students, and the meaning making process students undergo as they think about scientific knowledge and how people come to know what they know in science (an *emic* perspective). For instance, Urdan and Mestas (2006) used qualitative interview approaches to probe more deeply into the meanings that students gave about items from self-report instruments. In their study on goal orientations, the authors argued that "when researchers put the goals in the participants' mouths, so to speak," researchers may in fact be "limit[ing] the amount of information participants can offer" (p. 355).

This is also true with measures of epistemic beliefs. Karabenick et al. (2007) have suggested a method for exploring the meaning that students give to their survey responses as a way to address issues of validity. The Cognitive Pre-testing (CP) approach the authors advocated is an interesting direction for future work. By interviewing participants, researchers could probe and elicit responses about the meaning that participants give to items concerning epistemic beliefs about science. The CP method has been used to investigate survey responses for self-efficacy, achievement goal orientations, and self-regulated learning. Given the complexity of meanings students can give to epistemological assumptions in science, this could be a promising approach for future work with epistemic beliefs.

A second limitation lies in the fact that these data were collected only at one time point. Therefore, any claims of causality should be avoided. Furthermore, future work should be done to examine the changes in the multidimensional configuration of epistemic beliefs and implicit theories over time. For example, when students enter middle school are there quantitative and qualitative changes that occur as these students progress through middle school into high school and into college and even graduate work? Such empirical investigations could inform how these profiles change as students develop expertise in science.

Another limitation of the present study is related to the fact that I only explored motivational patterns that arose as a result of differences in epistemic beliefs. As discussed in the beginning of this chapter, the differences in the profiles with respect to epistemic beliefs were less obvious than the differences with respect to implicit theories of ability. In other words, it seemed like the implicit theory construct was more important than any of the dimensions of epistemic beliefs. However, implicit theories of ability are a motivation construct whereas epistemic beliefs are not. It would make sense, then, that implicit theories would explain more variance in constructs like self-efficacy or self-concept than would epistemic beliefs. Future work could address this limitation by also relating the emergent student profiles to cognitive and metacognitive constructs as well as performance measures on a task, which is what is traditionally explored in studies of epistemic beliefs.

Also, as mentioned earlier, even though I attempted to create profiles that were homogenous, the clusters within schools did contain students who were studying different science subjects. And as Dweck (1986) argued, different science subjects, especially in middle and high school, seem to involve new skills and completely different conceptual frameworks. Therefore, researchers would do well to investigate larger samples of students who are in similar science classes and grade levels. Researchers who address this limitation could investigate profiles that emerge within a particular subject in science, and explore whether they differ from those that emerge in other science subjects.

Finally, although the present study speaks to the correlates of implicit theories of ability and epistemic beliefs, it says nothing about the possible antecedents of these beliefs. Exploring the sources that fuel these beliefs may help science educators craft classroom environments and interventions that encourage students to think more incrementally about their science abilities, especially when they experience difficulties. Such research could also inform educators about how to craft science activities that portray science as an interconnected and socially constructed process that constantly evolves with new information gained from ongoing research.

Some have suggested (e.g., Bell & Linn, 2002) that by portraying science as more complex and by connecting science to students' everyday lives, students come to understand science on a deeper level and place more personal value in it. However, it is not yet clear what types of constructivist science instruction contribute to the development or constraining of epistemic beliefs and implicit theories of ability. Furthermore, it is not clear which types of constructivist instruction are better *for whom*. For example, do students who believe their science abilities are static respond differently to constructivist science instruction than do those who hold an incremental view? Do students who embody their cultural belief of esteeming the knowledge of external authorities respond differently to constructivist instruction that encourages them to actively question scientific claims? Future work should examine how different instructional approaches in science relate to changes in students' beliefs about science, and how these changes relate to individual differences and demographic factors. After all, science is neither context nor culture free, as some mistakenly assume, and science instruction is not one-size fits all (Lee, 2005).

Instruction that recognizes the cultural and contextual nature of science attends to students' individual differences and cultural backgrounds. By connecting school science to students' lives, science becomes relevant, and as Alfred North Whitehead (1929/1967) argued nearly a century ago in his treatise *The Aims of Education*, "theoretical ideas should always find important applications within the pupil's curriculum … [this doctrine] contains within itself the problem of keeping knowledge alive, of preventing it from becoming inert, which is the central problem of all education" (p. 5). Inert ideas, as Whitehead argued, are not only useless, they are "above all things, harmful—*Corruptio optima pessima*" (the corruption of the best is the worst of all). By seeing connections between science, current events, mathematics, and the daily lives of ordinary people, students can view science as dynamic, highly interconnected, even controversial. When students develop their conceptions of scientific knowledge and come to learn that their ability to do science is a malleable quality, they place themselves in a better position to become lifelong science learners.

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APPENDIX A:
Permission to Conduct Research

GWINNETT COUNTY PUBLIC SCHOOLS

GWINNETT COUNTY BOARD OF EDUCATION

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THE MISSION OF GWINNETT COUNTY PUBLIC SCHOOLS
is to pursue excellence in academic knowledge, skills, and behavior for each student, resulting in measured improvement against local, national, and world-class standards.

437 Old Peachtree Road, NW
Suwanee, GA 30024-2978
678-301-6000
www.gwinnett.k12.ga.us

It is the policy of Gwinnett County Public Schools not to discriminate on the basis of race, color, sex, religion, national origin, age, or disability in any employment practice, educational program, or any other program, activity, or service.

February 4, 2009

Mr. Jason Chen
Division of Educational Studies
Emory University
1784 N. Decatur Rd.
Suite 240
Atlanta, GA 30322

Re: File ID 2009-49

Dear Mr. Chen:

This is to advise you that your research proposal, "Implicit Theories of Ability, Epistemological Beliefs, and Science Motivation: A Mixed-Methods Approach (File ID 2009-49), has been approved with the following limitations:

- Participation in the proposed study will depend on the principal's and the teachers' opportunities and choice to accommodate the procedures.
- Survey administration scheduling must provide for minimal interference with science instructional time. The researcher and collaborating school personnel are encouraged to seek non-instructional time or advisement time for survey activities.
- The survey may only be administered to students with signed consent forms.

Important: **When contacting schools regarding this research, it is your responsibility to provide a copy of this approval letter to the principal**. In addition, it is your responsibility to provide your sponsors and project officers or managers with a copy of this approval letter. **Be sure to use the file ID number issued above when contacting schools or district level personnel regarding this research study**.

Please note that schools and teachers may elect not to participate in your research study, even though the district has granted permission.

Please forward a copy of your results to me when they are completed. Also, we would appreciate you providing us with feedback on the research approval process by completing the enclosed survey and returning it in the enclosed postage-paid envelope.

Best wishes for a successful research project. Please call me at (678) 301-7090 if I may be of further assistance.

Sincerely,

Colin Martin, Ph.D., Executive Director
Research and Evaluation

Cc: Jason Chen, jchen04@emory.edu

Enclosure

Academic Year 2008-2009

Dear Parent or Guardian:

My name is Jason Chen, and I am a former Gwinnett County High School chemistry and physics teacher currently on leave to complete my doctorate in education at Emory University. As part of my work at Emory, I will be conducting a study of students' motivation to do science. Information from this study will provide science teachers with greater insight about their students' motivation in science class and will help them better understand how they might encourage students to fully develop their skills in science.

All students will be asked to complete a brief survey in their science class that will take no more than 30 minutes to complete. I will also collect science achievement data about your child in the form of science midterm and end-of-term grades. Even though no private questions will be asked on the survey, ***all information will be kept strictly confidential***. Inclusion of your child's data in the research is voluntary. So if you do not want your child's data to be included in this research or if you do not want me to collect science achievement data about your child you may indicate that below. By declining permission for your child to participate in the study, your child will still take the survey, but the data will not be used and no science achievement data will be collected. The Offices of Research and Evaluation at both Gwinnett County Public Schools and at Emory University have approved this study.

Please fill out the form below by ***March 16, 2009***, and have your child return it to her/his science teacher. If you have any questions regarding the study feel free to contact me via email: jchen04@emory.edu. I am happy to help explain anything that may be unclear.

Sincerely,
Jason Chen

_ _

PLEASE CUT ALONG LINE AND RETURN BOTTOM PORTION

1) Name of Student (Please **PRINT** neatly): ____

2) Please check one of the boxes below:

☐ I **grant permission** for my child's data to be included in your study of science academic motivation.

☐ I prefer that my child's data **not** be included in your study of science academic motivation.

Parent/Guardian Signature: ____ Date: ____________

Parent/Guardian Name (Please **PRINT** neatly): ____

APPENDIX B:
Instrument

Implicit Theories of Science Ability:

Fixed View

1. You have a certain amount of science ability, and you really can't do much to change it.
2. Your science ability is something about you that you can't change very much.
3. You can learn new things in science, but you can't really change your basic science ability.

Incremental View

1. No matter who you are, you can change your science abilities a lot.
2. No matter how much science ability you have, you can always change it quite a bit.
3. You can always change how much science ability you have.

Epistemological Beliefs About the Nature of Science:

Source

1. Everybody has to believe what scientists say.
2. In science, you have to believe what the science books say about stuff.
3. Whatever the teacher says in science class is true.
4. If you read something in a science book, you can be sure it's true.
5. Only scientists know for sure what is true in science.

Certainty

1. All questions in science have one right answer.
2. The most important thing about doing science is coming up with the right answer.
3. Scientists pretty much know everything about science; there is not much more to know.
4. Scientific knowledge is always true.
5. Once scientists have a result from an experiment, that is the only answer.
6. Scientists always agree about what is true in science.

Development

1. Some ideas in science today are different than what scientists used to think.
2. The ideas in science books sometimes change.
3. There are some questions that even scientists cannot answer.
4. Ideas in science sometimes change.
5. New discoveries can change what scientists think is true.
6. Sometimes scientists change their minds about what is true in science.

Justification

1. Ideas about science experiments come from being curious and thinking about how things work.
2. In science, there can be more than one way for scientists to test their ideas.
3. One important part of science is doing experiments to come up with new ideas about how things work.

4. It is good to try experiments more than once to make sure of your findings.
5. Good ideas in science can come from anybody, not just from scientists.
6. A good way to know if something is true is to do an experiment.
7. Good answers are based on evidence from many different experiments.
8. Ideas in science can come from your own questions and experiments.
9. It is good to have an idea before you start an experiment.

Science Grade Self-Efficacy

1. How confident are you that you will pass your science class at the end of this semester?
2. How confident are you that you will get a grade of "C" or better in science this semester?
3. How confident are you that you will get a grade of "B" or better in science this semester?
4. How confident are you that you will get a grade of "A" or better in science this semester?

Science Achievement Goal Orientations

Task Goal Orientation

1. I like science assignments I can learn from, even if I make a lot of mistakes.
2. An important reason I do my science assignments is because I like to learn new things.
3. I like science assignments that really make me think.
4. An important reason I do my science assignments is because I want to become better at science.
5. I do my science assignments because I am interested in them.

Performance-Approach Goal Orientation

1. I want to do better than other students in my science class.
2. I would feel successful at science if I did better than most of the other students in the class.
3. I would feel really good if I were the only student in class who could answer the teacher's questions about science.
4. I'd like to show my science teacher that I'm smarter than the other students in my science class.
5. Doing better than other students in science is important to me.

Performance-Avoid Goal Orientation

1. The reason I do science assignments is so the teacher won't think I know less than other students.
2. I do my science assignments so others in the class won't think I'm dumb.
3. One reason I might not participate in science class is to avoid looking stupid.
4. One of my main goals in science class is to avoid looking like I can't do my work.
5. It's important to me that I don't look stupid in science class.

6. An important reason I do my science assignments is so I won't embarrass myself.

Self-Efficacy for Self-Regulation

1. How well can you finish your homework on time?
2. How well can you study when there are other interesting things to do?
3. How well can you concentrate on your school work?
4. How well can you remember information presented in class and in your school books?
5. How well can you arrange a place to study at home where you won't be distracted?
6. How well can you motivate yourself to do schoolwork?
7. How well can you participate in class discussions?

Science Self-Concept

1. It is important to me to get good grades in science.
2. I am better at science than the other students in my class.
3. I am better at science than the other students in my grade.
4. Being good in science is important to me.
5. I enjoy doing science work.
6. Science is interesting for me.
7. Science is boring.
8. Science is a lot of fun.
9. I like to do science work.
10. I look forward to coming to science class.
11. I look forward to science lab.
12. I like completing laboratory assignments.

Interest in Pursuing STEM Occupations

1. Please write down up to three jobs that you realistically think you would like to pursue.

2. Please circle ONE of the three responses above that represents the job you would be most interested in pursuing.

3. Please indicate how confident you are that you will pursue the job you circled above (1 = Not at all confident; 6 = Completely confident).